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Managing Editor
Joel W. Snodgrass
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Department of Biological Sciences
Towson University
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Graphics & Typesetting
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Distributions and Habitat Associations of Four State Imperiled Freshwater Fish Species in Zekiah Swamp, Prince George's and Charles Counties, Maryland

Patrick J. Ciccotto[2] *and Scott A. Stranko*[3]

[2]Corresponding Author, Maryland Department of Natural Resources, Monitoring and Non-tidal Assessment, 580 Taylor Avenue , Annapolis, MD 21401, pciccotto@dnr.state.md.us.

[3]Maryland Department of Natural Resources, Monitoring and Non-tidal Assessment, 580 Taylor Avenue , Annapolis, MD 21401, sstranko@dnr.state.md.us.

Abstract.—Zekiah Swamp supports a rich freshwater fish assemblage, including four state imperiled species: ironcolor shiner (*Notropis chalybaeus*), flier (*Centrarchus macropterus*), warmouth (*Lepomis gulosus*), and swamp darter (*Etheostoma fusiforme*). From 1995-2008, 46 sites were surveyed in Zekiah Swamp to determine the distributions of these state imperiled species and the habitats associated with them within this watershed. Ironcolor shiner and swamp darter are restricted to the mainstem of Zekiah Swamp, whereas warmouth and flier are found in the mainstem and several tributaries. These species were all associated with high quality pool habitats. Limiting landscape disturbances appears paramount to protecting these imperiled fishes.

Introduction

The Zekiah Swamp watershed is located in southern Maryland on the Atlantic Coastal Plain, forming the headwaters of the Wicomico River which drains into the lower Potomac River in Prince George's and Charles counties. Zekiah Swamp is approximately 28,280 ha in area and is underlain by unconsolidated sediments ranging in age from 135 million to one million years (Cretaceous to Pleistocene). The mainstem of the watershed, Zekiah Swamp Run, is a braided stream with several smaller intermittent tributaries flowing into it throughout its approximately 32 km long stretch. Both the mainstem and tributaries are influenced by seasonal precipitation, with the mainstem expanding onto the floodplain after significant wet periods and portions of both the mainstem and the tributaries drying during the summer months forming a series of isolated pools. Hardwood forest occupies most of the undisturbed floodplain and upland portions of the watershed (Tri-County Council for Southern Maryland and Charles County 1985).

Fish habitat in Zekiah Swamp Run and its larger tributaries is characterized by slow-moving pool-glides with silt/sand/gravel substrates and submerged logs and root wads serving as critical habitat features. Gravel riffles are present in the smaller tributaries. The Zekiah Swamp watershed contains a rich Coastal Plain fish assemblage. Eastern mudminnow (*Umbra pygmaea*), American eel (*Anguilla rostrata*), and redfin pickerel (*Esox americanus americanus*) comprise the dominant species. Four state listed fish species have been collected in Zekiah Swamp: ironcolor shiner (*Notropis*

[1]pciccotto@dnr.state.md.us

chalybaeus), flier (*Centrarchus macropterus*), warmouth (*Lepomis gulosus*), and swamp darter (*Etheostoma fusiforme*).

The Maryland Department of Natural Resources through the Maryland Biological Stream Survey (MBSS) has sampled for fish along with concomitant abiotic data in Zekiah Swamp at 46 different stations from 1995-2008, 28 of which were randomly selected for sampling (Fig. 1). Our goal was to describe in detail the distributions of the four species in Zekiah Swamp as well as investigate physical habitat and water chemistry variables associated with these species' occurrences.

Figure 1. Location of Zekiah Swamp in Maryland (inset) and locations of sites sampled by the Maryland Biological Stream Survey. Individual sites sampled from 1995-2008 are dark circles (●) if at least one state imperiled fish species was present and open circles (○) if no state imperiled fish species were observed.

Study Species

Ironcolor Shiner (Notropis chalybaeus)

The ironcolor shiner is native to the Hudson River in New York, south to Florida and west to Louisiana and eastern Texas (Lee et al. 1980). In Maryland, extant populations of ironcolor shiner occur in Zekiah Swamp, Nanjemoy Creek, and St. Mary's River in the lower Potomac River basin, as well in Tuckahoe Creek on the eastern shore. Historical records for this species exist in the Pocomoke, Nanticoke, and Susquehanna River basins (Kazyak et al. 2005). Ironcolor shiners typically inhabit low-gradient creeks, streams, beaver ponds, and swamps with fine particle substrates and submerged vegetation (Jenkins & Burkhead 1994; Snodgrass et al. 1998). The diets of ironcolor shiners consist of insect larvae, small crustaceans, and plant material. Spawning occurs in the spring and summer with females broadcasting eggs over vegetation or sand (Sheldon & Meffe 1993; Rohde et al. 1994; Leckvarcik 2001; Boschung & Mayden 2004). Ironcolor shiner is listed as "Endangered" in Maryland (Maryland Department of Natural Resources 2007).

Flier (Centrarchus macropterus)

The flier ranges from the Mississippi River in southern Illinois south to the Gulf and Atlantic slope drainages from eastern Texas to southern Maryland (Lee et al. 1980). In Maryland, extant populations are only known in Zekiah Swamp, Breton Bay, St. Mary's River, and Port Tobacco River, all draining into the lower Potomac River. This species typically inhabits the pools and backwaters of creeks to rivers as well as swamps, isolated wetlands, beaver ponds, and lakes and are often found in acidic conditions (Jenkins & Burkhead 1994; Snodgrass et al. 1996; Snodgrass et al. 1998). The diet of fliers consists of insects, crayfishes, and occasionally fishes. Males construct nests in early spring, similar to the spawning behavior of *Lepomis* species (Rohde et al. 1994; Boschung & Mayden 2004). Flier is listed as "Threatened" in Maryland (Maryland Department of Natural Resources 2007).

Warmouth (Lepomis gulosus)

Warmouth is native to the lower portions of the Great Lakes southward in the Mississippi drainages and along the Gulf and Atlantic slope drainages from Texas to southern Maryland (Lee et al. 1980). In Maryland it is found in several watersheds of the lower Potomac River, as well as portions of the Patuxent River and Chester River watersheds. Warmouth typically inhabit lotic and lentic habitats similar to those described for flier and can tolerate acidic as well as moderately saline water conditions (Jenkins & Burkhead 1994). Insects in addition to crayfishes and fishes comprise the diet of warmouth. Spawning occurs from spring to summer in proximity to woody debris or other cover, typically over soft substrates (Rohde et al. 1994; Boschung & Mayden 2004). Warmouth is on the "Watch List" in Maryland (Maryland Department of Natural Resources 2007).

Swamp Darter (Etheostoma fusiforme)

The swamp darter is native to the Atlantic slope from Maine, south to Florida and west on the Gulf Coast to eastern Texas (Lee et al. 1980). Zekiah Swamp is the only known location of an extant population of swamp darter on the western shore of Maryland. Other populations are known in the Chester River, Choptank River, Nanticoke/Wicomico River, and Pocomoke River basins on the eastern shore. The species

typically inhabits swamps and slow-moving creeks, streams, and rivers with muddy or sandy substrates, often in aquatic vegetation (Jenkins & Burkhead 1994). In lotic habitats, swamp darters are typically found in sluggish water, but have been observed in riffles (Schmidt & Whitworth 1979). Swamp darters feed on aquatic insects and microcrustaceans (Jenkins & Burkhead 1994; Schmidt & Whitworth 1979). Spawning occurs in spring with females attaching eggs to vegetation (Rohde et al. 1994; Boschung & Mayden 2004). The swamp darter is listed as "In Need of Conservation" in Maryland (Maryland Department of Natural Resources 2007).

Methods

Fish were sampled using Smith-Root Model 12 backpack electrofishing units. During the 1995-2007 surveys, fish collections consisted of double-pass electrofishing at low flow conditions from June-September with block nets at the upstream and downstream ends of a site to prevent fish movement. During the 2008 surveys (April-August), 15 sites were sampled over a minimum of 75 m of stream length without block nets, and sampling was concluded when 600 seconds of electrofishing produced no new species. One site was sampled exclusively with a 3 m seine (¼" mesh) due to high water conductivity not permitting effective electrofishing. Habitat and chemistry data were collected using the same methods for all sites. Water chemistry measurements (pH, conductivity, and dissolved oxygen) were collected using a Quanta Hydrolab. Physical habitat variables were measured using MBSS protocols in a 75 m stream reach. Instream habitat, epifaunal substrate, pool/glide/eddy quality, riffle/run quality, and velocity/depth diversity were each rated on a 0-20 scale using well-defined, quality controlled visual assessments (Stranko et al. 2007). Instream habitat scores were assigned based on perceived value of habitat for fishes. Sites with a variety of habitat types and substrate particle sizes received higher instream habitat scores. Epifaunal substrate scores were assigned based on the amount and variety of hard, stable substrates usable by benthic macroinvertebrates. Higher scores were assigned to sites with stable substrates free of flocculent materials or fine sediments. Pool/glide/eddy quality scores were assigned based on the variety and complexity of slow- or still-water habitat at a site. Higher scores were assigned to segments with undercut banks, woody debris, and other potential types of cover for fishes. Riffle/run quality scores were assigned on riffle/run depth, complexity, and functional importance. Segments with deeper riffle/run areas, stable substrates, and a variety of water current velocities received the highest scores. To analyze patterns of physical habitat and water chemistry in relationship to the distributions of the four imperiled fish species, we used non-metric multidimensional scaling (NMS), a multivariate ordination technique. An outlier analysis was conducted prior to the NMS and eliminated three sites from the 1995-2008 surveys for a total of 43 sites entered into the ordination. We used PC-ORD to conduct the NMS (McCune & Mefford 2006).

Results

A list of species collected in the Zekiah Swamp watershed from 1995-2008 and the number and percentage of sites they were collected at are presented in Table 1. Ironcolor shiners, fliers, warmouth, and swamp darters were collected at 3 (6.5%), 10

(21.7%), 17 (37.0%), and 5 (10.9%) sites during the 2008 survey, respectively. Ironcolor shiners and swamp darters were restricted to the mainstem of Zekiah Swamp. Fliers were collected in Zekiah Swamp Run and several tributaries in the northern part of the watershed. Warmouth had the most widespread distribution of the imperiled species, and was found throughout the mainstem from the tidal-fresh portion of Zekiah Swamp Run to several tributaries throughout the watershed. Sites where no imperiled fish species were collected were mainly small, shallower first and second order streams with little woody debris. Imperiled species were never abundant except at one site with where 63 fliers and 34 warmouths were collected in a 95 m reach of stream.

The NMS plot of axes 1 and 2 for the Zekiah Swamp sites (Fig. 2) illustrates pool/glide quality, riffle/run, and dissolved oxygen gradients on axis 1. Variables strongly associated with axis 1 included dissolved oxygen (r = 0.72), pool/glide quality (-0.60), and riffle/run quality (r = 0.58). A pool/glide quality gradient is also represented by axis 2 (r = 0.53). The coefficients of determination of the correlation between the distances in original and ordinated space for axes 1 and 2 were 31.2% and 9.5%, respectively. Sites where warmouth, fliers, swamp darters, and ironcolor shiners were present are located in the area of higher pool/glide quality in ordination space.

Figure 2. Nonmetric multidimensional scaling ordination plots of habitat variables at sites where *Lepomis gulosus*, *Centrarchus macropterus*, *Etheostoma fusiforme*, and *Notropis chalybaeus* were present (●) and absent (○) in Zekiah Swamp. Habitat variables strongly correlated with axes 1 and 2 are illustrated.

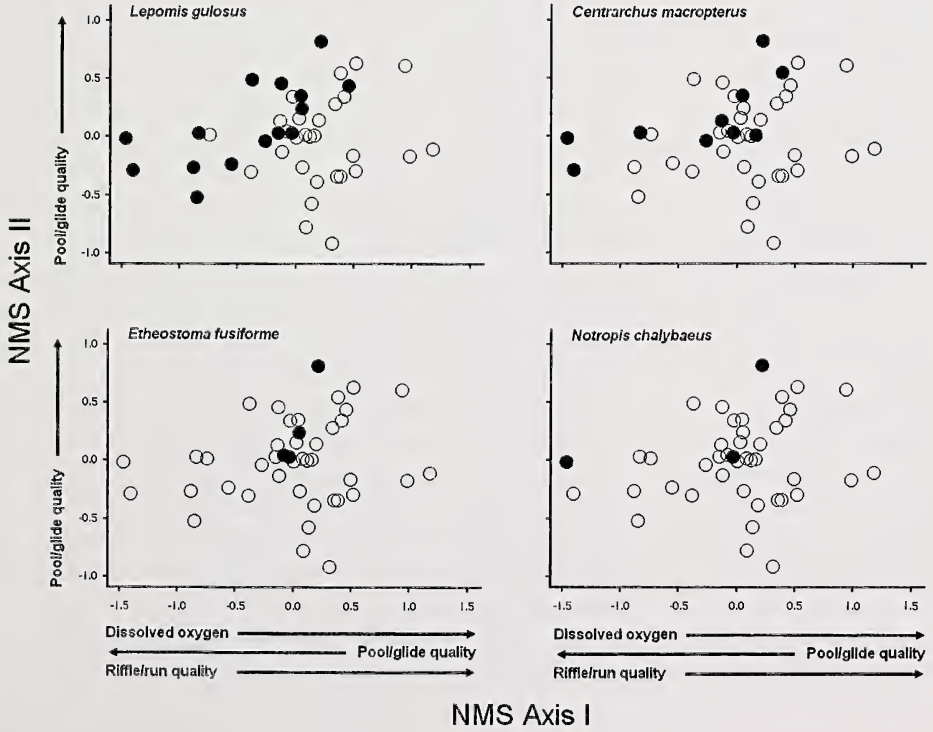

Table 1. Percent occurrence of fish species collected by the Maryland Biological Stream Survey from 1995-2008 at sites in Zekiah Swamp.

Scientific Name	Common Name	Number of Occurrences	Percent Occurrence
Lampetra aepyptera	Least brook lamprey	25	54.3
Petromyzon marinus	Sea lamprey	7	15.2
Anguilla rostrata	American eel	39	84.8
Dorosoma cepedianum	Gizzard shad	1	2.2
Clinostomus funduloides	Rosyside dace	23	50.0
Hybognathus regius	Eastern silvery minnow	1	2.2
Luxilus cornutus	Common shiner	1	2.2
Notemigonus crysoleucas	Golden shiner	11	23.9
Notropis chalybaeus	Ironcolor shiner	3	6.5
Notropis hudsonius	Spottail shiner	1	2.2
Rhinichthys atratulus	Eastern blacknose dace	17	37.0
Semotilus corporalis	Fallfish	30	65.2
Catostomus commersoni	White sucker	4	8.7
Erimyzon oblongus	Creek chubsucker	26	56.5
Ameiurus catus	White catfish	1	2.2
Ameiurus natalis	Yellow bullhead	1	2.2
Ameiurus nebulosus	Brown bullhead	7	15.2
Noturus gyrinus	Tadpole madtom	14	30.4
Noturus insignis	Margined madtom	24	52.2
Umbra pygmaea	Eastern mudminnow	43	93.5
Esox a. americanus	Redfin pickerel	34	73.9
Esox niger	Chain pickerel	15	32.6
Aphredoderus sayanus	Pirate perch	25	54.3
Fundulus diaphanus	Banded killifish	1	2.2
Gambusia holbrooki	Eastern mosquitofish	8	17.4
Centrarchus macropterus	Flier	10	21.7
Enneacanthus gloriosus	Bluespotted sunfish	13	28.3
Lepomis auritus	Redbreast sunfish	1	2.2
Lepomis cyanellus	Green sunfish	4	8.7
Lepomis gibbosus	Pumpkinseed	30	65.2
Lepomis gulosus	Warmouth	17	37.0
Lepomis macrochirus	Bluegill	32	69.6
Micropterus salmoides	Largemouth bass	18	39.1
Pomoxis nigromaculatus	Black crappie	2	4.3
Etheostoma fusiforme	Swamp darter	5	10.9
Etheostoma olmstedi	Tessellated darter	31	67.4
Perca flavescens	Yellow perch	1	2.2
Leiostomus xanthurus	Spot	1	2.2

On average, all four imperiled fish species were found at sites with higher quality pool habitat. Ironcolor shiners, fliers, warmouths, and swamp darters were collected at sites with mean pool/glide quality scores of 16.3, 13.6, 14, and 15 respectively. The lowest pool/glide quality score at a site with an imperiled fish species present was 8 (swamp darter and warmouth). All four species were collected at sites with dissolved oxygen concentrations less than 3 mg/L.

Discussion

Ironcolor shiners, fliers, swamp darters, and warmouth are all at the edges of their geographic distributions in Maryland. Populations at the periphery of their distribution often occur in sub-optimal habitats and are fragmented from other populations in the core of the species' range (Lesica & Allendorf 1995). This is likely the main factor in the inherent rarity of these fish species in Zekiah Swamp. However, habitat scale variables also appear to play a role. These imperiled fishes were all associated with deep pool habitats with complex habitat structures. Pool habitats appear to be more important than the chemical variables examined here, particularly dissolved oxygen. The concentrations of dissolved oxygen were often low at sites where these species were present as a result of little or no surface disturbance limiting the exchange of atmospheric oxygen with the stream water.

The historical extirpation of beavers (*Castor canadensis*) may play an additional role in the imperilment of these fishes as well. Following the advent of European colonization came the trapping of beavers for their fur, which was extirpated from the Maryland Coastal Plain (Naiman et al. 1988). The U.S. Fish and Wildlife Service reintroduced beavers into the region in the 1970's where populations have since been on the rise (Correll et al. 2000). Impoundments created by beaver dams likely play a critical role in structuring the preferred habitats of these imperiled fishes, specifically the creation of deep pools and the input of woody debris for cover. The extirpation of beavers likely contributed to a decline of these habitats and rare fish species in southern Maryland. Management of beaver populations in Zekiah Swamp and the lower Potomac River should be addressed in regards to the conservation of these imperiled fishes.

Pool depth and instream physical habitat features are the driving mechanisms in maintaining species richness in Coastal Plain fish assemblages, particularly in intermittent streams (Meffe & Sheldon 1988; Dekar & Magoulick 2007). While these species are adapted to fluctuating seasonal water conditions, anthropogenic landscape changes, specifically the removal of forest land, may greatly hinder the ability of these species to persist in these naturally stressed environments. Woody debris from riparian trees serve as habitat structure and can deepen pools through increased hydraulic scour (Sheldon & Meffe 1993; Matthews 1998). Canopy cover aids in the regulation of stream temperatures and primary productivity as well (Roy et al. 2005). Deforestation negatively impacts pool habitat features through the loss of streamside cover and instream woody debris, eliminating cover from predators, spawning habitat, and protection from solar radiation (Pollock et al. 2005). Non-native species, including bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*) and red swamp crayfish (*Procambarus clarkii*) that were collected during these surveys also pose a potential threat through competi-

tion and predation, particularly during drought conditions in the confined pool areas (Capone & Kushlan 1991). The combination of all of these factors should be expected to negatively impact the native ichthyofauna in Zekiah Swamp. Inherently rare species, such as ironcolor shiner, flier, warmouth, and swamp darter are at the greatest risk with restricted distributions and low population numbers limiting the ability of these species to recover from watershed degradation and the introduction of exotic species.

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Observations of Indiana myotis roosting and foraging behavior in Carroll County, Maryland

JOSHUA B. JOHNSON[1] *AND J. EDWARD GATES*

[1]Appalachian Laboratory, University of Maryland Center for Environmental Science (UMCES), 301 Braddock Road, Frostburg, Maryland 21532.

ABSTRACT.—Federally endangered Indiana myotis (*Myotis sodalis*) were discovered migrating from central Pennsylvania to northern Carroll County, Maryland, in spring 2005. However, it was unclear if these bats remained in northern Carroll County during the summer maternity season. We used acoustic monitoring, mist netting, and radio telemetry methods to evaluate the presence, roosting, and foraging behavior of Indiana myotis in northern Carroll County in summer 2007. We captured 403 bats, including three Indiana myotis. We captured two post-lactating Indiana myotis near Wentz. We captured one juvenile male Indiana myotis near Taneytown. A weak transmitter prevented us from obtaining any meaningful data from one of the females. We were unable to gain access to the private property on which the other female was roosting. However, we were able to determine a 95% fixed kernel home range of 31.5 ha for this bat, which foraged preferentially in forest cover. The juvenile male roosted in two American elm (*Ulmus americana*) snags. Exit counts revealed one and six bats roosting in the trees, including the radio tagged bat. The juvenile male had a 95% fixed kernel home range of 425.4 ha, and foraged mostly over agricultural fields and along tree lines. Of the 15,535 echolocation passes we collected, 114 were recorded from Indiana myotis among four properties where they had been previously documented. This study confirms that Indiana myotis establish maternity colonies in the Wentz and Taneytown areas. Further research examining the roosting and foraging ecology of the Taneytown and Wentz colonies throughout the summer, and efforts to determine Indiana myotis distribution during summer in Maryland are warranted.

INTRODUCTION

Indiana myotis (*Myotis sodalis*) were listed as an endangered species in 1967 under the Endangered Species Act of 1966 because of significant population declines. Census data collected in the early 2000s indicated that Indiana myotis populations have experienced a noticeable increase throughout their range, which includes the Midwestern United States, east to the Appalachian Mountains, and north through New England, but are well below levels documented in the 1960s (Thomson 1982; USFWS 2007). Indiana myotis population recovery efforts have included protection of known hibernacula, and research examining their summer ecology and distribution. Hibernacula protection is critical to Indiana myotis population recovery, and conservation of summer habitat is equally imperative (USFWS 2007).

Although Indiana myotis had been the focus of a considerable amount of research across its range, the ecology of this species in the eastern United States remains poorly understood (Callahan et al. 1997; Butchkoski & Hassinger 2002; Menzel et al. 2005; Britzke et al. 2006). Until recently, summer distributions of Indiana myotis in

[1]j-johnson3@juno.com

the eastern United States were unclear. Indiana myotis begin to emerge from hibernation in mid-April and migrate long distances, sometimes over 500 km, to their summer ranges (Cope & Humphrey 1977; Kurta & Murray 2002). Therefore, the summer range of Indiana myotis hibernating in the Appalachian Mountains potentially could include a large area, from the Atlantic coast to the Mississippi River drainage. In New York, female Indiana myotis migrated ≤40 km from their hibernaculum to spring roost trees (Britzke et al. 2006). In western Virginia, a male Indiana myotis migrated 16 km from its hibernaculum to an area where it remained for 2 weeks (Hobson & Holland 1995). In West Virginia, a radio-tagged male Indiana myotis roosted in trees within a few kilometers of its hibernaculum during summer (Ford et al. 2002). In spring 2005, two female Indiana myotis were documented migrating approximately 150 km from their hibernaculum near Altoona, Pennsylvania, to two areas in northern Carroll County, Maryland; one near Taneytown and one near Wentz (Butchkoski & Turner 2005). Although several roost trees were identified, it was unclear if these bats remained in the respective areas throughout the maternity season (D. Limpert, Maryland Department of Natural Resources, personal communication). Until 2005, few records of Indiana myotis existed for Maryland, and those were from autumn swarming surveys at caves, mines, and a tunnel in the western third of the state (Paradiso 1969; Gates et al. 1984; Marsh 1998; Johnson & Gates 2007). It is unclear if Indiana myotis have been documented hibernating in Maryland (Gates et al. 1984). Our objective was to conduct mist netting and acoustic surveys for bats in the Taneytown and Wentz areas, as well as other areas in northern Carroll County, specifically to determine presence of Indiana myotis maternity colonies and to provide information on their roosting and foraging ecology.

STUDY AREA

We conducted our research in northern Carroll County, Maryland, specifically in the Taneytown, Wentz, and Westminster areas where Indiana myotis had either been previously documented or potentially occurred. We contacted landowners before conducting research on their properties. In the Taneytown area, we focused our efforts on properties along Big Pipe Creek where Indiana myotis roost trees were identified in 2005. In the Westminster area, we conducted our surveys at the Hashawha Environmental Center. In the Wentz area, we surveyed on or adjacent to properties where roost trees were identified in 2005. All of the properties we surveyed were located in the Piedmont physiographic province (Schmidt 1993). The area was characterized by rolling hills of low relief, with elevations ranging from 140 to 350 m. Low gradient streams and rivers, and farm ponds occurred throughout the area. The predominant land cover types in the area were fields of row crops, hay, and pasture. Forests occurred as riparian zones and woodlots, and were comprised mostly of oaks (*Quercus* spp.) and hickories (*Carya* spp.). Mean summer (June–August) temperature in the Westminster area is 22.2°C, and precipitation averages 110.9 cm annually (NOAA 2005). During our fieldwork, the region was experiencing abnormally dry to moderate drought conditions.

METHODS

Mist netting and harp trapping. To capture bats, we used 50-denier, 2-ply, 38 mm-mesh mist nets measuring 2.6 m high and 6, 9, or 12 m long (Avinet, Dryden,

New York), and harp traps (1.8 m × 2.3 m; Bat Conservation and Management, Carlisle, Pennsylvania). Mist nets and harp traps typically were placed over stream or road corridors, along forest edges, and adjacent to or over ponds. We used 1 to 3 tier mist net arrangements. A 2 or 3-tier mist net arrangement consisted of 2 or 3 mist nets stacked vertically and suspended between a rope and pulley system on 2 to 10 m telescoping poles. Sampling was conducted for 5 hours following sunset. The species of each captured bat was determined as well as its weight, forearm length, sex, age, and reproductive condition (Anthony 1988; Racey 1988; Menzel et al. 2002b). Bats were marked with non-toxic, temporary paint pens to facilitate identification of recaptures. We also wing-banded Indiana myotis for long-term monitoring of their activity (48.5 mg; Porzana Ltd., Icklesham, East Sussex, United Kingdom). Males and females were banded on their right and left forearms, respectively.

Acoustic monitoring. We used an Anabat II (Titley Scientific, Ballina, Australia) broadband, frequency-division, bat detector to passively monitor for bat echolocation passes (i.e., a series of echolocation pulses; Schnitzler & Kalko 1998). The detector was located near mist netting sites and was suspended from a tree limb 1 to 2 m above the ground, or placed on the ground, pointed up at a 45° angle. We conducted acoustical monitoring concurrently with mist netting. Echolocation passes were recorded on an Anabat CompactFlash storage Zero-Crossing Analysis Interface Module (ZCAIM) and downloaded to a computer for analysis using Analook 4.8p software (Corben 2001). We used qualitative and quantitative echolocation pass identification methods (Fenton & Bell 1981; O'Farrell et al. 1999; Murray et al. 2001). We identified echolocation passes by comparing the structure (e.g., frequency-modulated, quasi-constant frequency), frequency, and change in octaves per second of our unknowns to a library comprised of echolocation passes collected from hand-released bats marked with chemiluminescent tags collected throughout the southeastern and mid-Atlantic United States (Fenton & Bell 1981; O'Farrell et al. 1999; Murray et al. 2001; Menzel et al. 2002a). We only attempted identification of echolocation passes containing greater than or equal to 3 pulses (Johnson et al. 2002). Our identifications were limited to species, as no techniques exist to reliably distinguish male and female or adult and juvenile bat echolocation calls. Moreover, quantity of echolocation passes recorded is an index of activity and does not necessarily reflect the quantity of bats being recorded (i.e., one bat can be recorded multiple times; Broders 2003).

Diurnal roost evaluations. We examined bat boxes that were erected on properties throughout the study area in 2006 for roosting bats. We checked barns for roosting bats based on landowner reports of bat use. During the day and at dusk, we inspected Indiana myotis roost trees for roosting bats. The Pennsylvania Game Commission and Maryland Department of Natural Resources identified these roost trees in spring 2005.

Radio telemetry. We documented roosting and foraging behavior of Indiana myotis through radio telemetry methods. We used surgical cement (Torbot Group, Cranston, Rhode Island, USA) to affix a 0.35 g radio transmitter (Model LB-2N; Holohil Systems Ltd., Carp, Ontario, Canada) between the scapulae of captured Indiana myotis. The transmitter weight to animal body weight (mean ± 1 SD; 7.3 ± 1.2 g) percentage (4.8 ± 0.9%) was similar to percentages in other Indiana myotis studies (Kurta & Murray 2002; Kurta et al. 2002; Britzke et al. 2003, 2006; Menzel et al. 2005). We used radio

receivers and 3-element Yagi antennae (Advanced Telemetry Systems, Inc., Isanti, Minnesota, USA) to determine roosting and foraging locations.

We located diurnal roosts and examined characteristics of those sites. Within a 10-m radius centered on the roost, we determined degree of slope with a clinometer, slope aspect with a compass, number of trees, number of snags, mean diameter at breast height (DBH) and total height of all trees within the plot, height of roost, and distance from the roost tree to the nearest overstory tree.

We examined foraging behavior of each bat by simultaneously obtaining two directional bearings from known locations (i.e., telemetry stations) at greater than or equal to 5-minute intervals. Telemetry stations were positioned to minimize distances to radio-tagged bats and to reduce associated location error. Bearings were obtained from the time the bat emerged from its diurnal roost until about 0200 hours. We entered bearings and telemetry station locations into Locate III to obtain Universal Transverse Mercator (UTM) coordinates of each foraging location (Nams 2006). We entered capture location, foraging location, and diurnal roost location coordinates for each bat into ArcView 3.2 (Environmental Systems Research Institute, Redlands, California, USA) and used the Animal Movement Extension to calculate home ranges using the fixed kernel method based on 95, 75, and 50% confidence intervals to exclude outliers (Worton 1989; Hooge & Eichenlaub 1997; Seaman et al. 1999).

We examined habitat use of bats for which we obtained greater than 30 locations. We converted a raster land use/land cover (LULC) theme from the United States Geological Survey Gap Analysis Program to a LULC vector shapefile in ArcView 3.2 (USGS 2000). From the LULC vector shapefile, we created a separate vector shapefile for each LULC type, including developed areas, fields, forests, and water. We combined the LULC-based water shapefile with separate National Hydrography Dataset for streams and ponds, to create a single shapefile that represented water. We also included a separate vector shapefile that represented paved roads in the analysis for a total of five LULC types. We used distance-based analysis to examine habitat use of radio-tagged bats because it reduces the effect of radio telemetry error and Type I error commonly associated with other habitat use analyses, including compositional analysis (Conner et al. 2002; Bingham & Brennan 2004). For each bat, we determined the maximum distance a foraging or capture location was from its diurnal roost or geometric mean if greater than one diurnal roost. This maximum distance served as a radius for a buffer around the center of each bat's diurnal roost locations. We paired each foraging location with a location that was randomly located within the buffer. We determined minimum Euclidean distances from every foraging and random location to every LULC type. We used a Wilcoxon test to examine differences between foraging and random location distances to each LULC type (SAS Institute, Inc. 2004; PROC NPAR1WAY). We used an analysis of variance to examine differences among mean distances from foraging locations to each LULC type (SAS Institute, Inc. 2004; PROC GLM). Multiple means comparisons were analyzed using Duncan's New Multiple Range Test. Statistical significance for all analyses was $P \leq 0.05$.

RESULTS

Mist netting and harp trapping. We surveyed for bats at 13 sites among seven private properties near Taneytown, Wentz, and Westminster, Maryland. From 2 July to

16 August 2007, our efforts included 146 mist-net nights during 27 nights of surveying. We captured 403 bats, including 184 little brown myotis (*Myotis lucifugus*), 127 big brown bats (*Eptesicus fuscus*), 40 eastern red bats (*Lasiurus borealis*), 38 northern myotis (*M. septentrionalis*), 9 tri-colored bats (*Perimyotis subflavus*; formerly known as the eastern pipistrelle [*Pipistrellus subflavus*]), 3 Indiana myotis, and 2 hoary bats (*L. cinereus*; Table 1). We captured reproductive females of all seven species except hoary bats, and juveniles of all seven species. We captured two post-lactating Indiana myotis near Wentz, one on 21 July and one on 24 July. The Indiana myotis captured on 21 July was mist netted over a dirt road leading to a hayfield. The Indiana myotis captured on 24 July was mist netted near small ponds. We neglected to wing band the female captured on 21 July, but did wing band (MDDNR 55039) the female captured on 24 July. We captured one juvenile male Indiana myotis (wing band MDDNR 55040) in a mist net over Big Pipe Creek near Taneytown on 7 August. Overall capture per unit effort (CPUE) was 0.0235 bats per m^2 of mist net per hour (Table 2). A typical night of mist netting consisted of monitoring four 12 m mist nets (one single tier net and one triple tier mist net) totaling 124.8 m^2 for 5 hours (624 mist net hours). A CPUE of 0.0235 times 624 mist net hours equals about 15 bats captured per night. Little brown myotis, big brown bats, and eastern red bats had the highest capture rates and were the most ubiquitous of the seven captured species. We recaptured 11 bats; 2 big brown bats, 2 little brown myotis, and 1 northern myotis were recaptured within the same night, and 5 big brown bats and 1 little brown myotis were recaptured on subsequent nights.

Acoustic monitoring. We recorded 15,535 echolocation passes among 12 sites during 26 nights of acoustic monitoring (Table 3). We acoustically recorded the same species that were documented using capture methods. We recorded 114 echolocation passes from Indiana myotis at six locations on four private properties.

Diurnal roost evaluations. We examined ten bat boxes and two barns for roosting bats on four properties once each. Two bat boxes had bats roosting in them; 1 little brown myotis roosting in one bat box, and 1 big brown bat and 9 little brown myotis roosting in the other. A big brown bat was observed roosting in a barn. We examined three trees on two properties for roosting bats during the day and at dusk. We observed no roosting bats in any of the trees during the day. However, we counted 5 bats emerging from a shagbark hickory (*Carya ovata*) that was identified as a roost tree in 2005 and seven bats emerging from an adjacent shagbark hickory. We could not determine species based on our observations because the bats emerged from the boles of the trees greater than 10 m above the ground. We observed no bats emerging at dusk from a mockernut hickory (*Carya tomentosa*) identified as a roost tree in 2005. On two properties near Taneytown, we noticed concentrations of bat activity along tree lines, possibly as bats were flying from their diurnal roost trees to their foraging areas. We had high capture rates of little brown myotis during these occasions.

Radio Telemetry. We conducted radio telemetry on the three Indiana myotis we captured. A weak transmitter prevented us from determining any roosting locations for the female captured on 21 July, despite extensive searching within 2 km of the capture site for 4 days following capture. The Indiana myotis we captured on 24 July roosted on a property adjacent to the property on which it was captured. We were unable to obtain permission to access the property, so we triangulated the diurnal roost of the bat on three

Table 1. Bat captures in Carroll County, Maryland, July–August 2007.

Area	Site no.	Date	Species	No. captures*	Male		Female	
					A	J	A	J
Hashawha	A	7/2/2007	*Lasiurus borealis*	4	4	0	0	0
			Myotis lucifugus	2	1	0	1	0
			Myotis septentrionalis	1	0	0	1	0
			Perimyotis subflavus	5	2	0	3	0
Hashawha	B	7/3/2007	*Eptesicus fuscus*	6	2	0	4	0
			Lasiurus borealis	2	0	0	1	0
			Myotis lucifugus	3	0	0	3	0
			Myotis septentrionalis	6	0	0	6	0
Hashawha	A	7/6/2007	*Eptesicus fuscus*	1	1	0	0	0
			Lasiurus borealis	1	1	0	0	0
			Myotis lucifugus	4	0	0	3	1
Hashawha	B	7/9/2007	*Eptesicus fuscus*	5	3	0	2	0
			Lasiurus borealis	1	1	0	0	0
			Myotis lucifugus	9	0	2	6	1
Taneytown	C	7/10/2007	*Eptesicus fuscus*	6	2	2	2	0
			Lasiurus borealis	2	0	1	1	0
			Myotis lucifugus	44	4	8	19	13
Taneytown	D	7/12/2007	*Eptesicus fuscus*	8	0	3	3	2
			Lasiurus borealis	1	0	0	1	0
			Myotis lucifugus	11	0	0	7	4
Taneytown	E	7/13/2007	*Eptesicus fuscus*	3	1	0	1	0
			Lasiurus borealis	1	0	0	0	1
			Myotis lucifugus	39	3	4	24	7
			Myotis septentrionalis	6	0	1	3	2
Taneytown	F	7/16/2007	*Eptesicus fuscus*	7	1	3	1	2
			Lasiurus borealis	1	0	0	0	1
			Lasiurus cinereus	1	0	1	0	0
			Myotis lucifugus	23	0	4	11	8
			Myotis septentrionalis	3	0	1	2	0
Wentz	G	7/17/2007	*Eptesicus fuscus*	4	0	1	1	2
Wentz	G	7/18/2007	*Eptesicus fuscus*	3	0	1	2	0
			Lasiurus borealis	1	0	0	0	1
			Myotis lucifugus	1	0	1	0	0
			Myotis septentrionalis	3	0	2	0	1
Wentz	H	7/19/2007	*Eptesicus fuscus*	22	6	5	8	1
			Lasiurus borealis	2	1	1	0	0
			Myotis lucifugus	1	1	0	0	0
			Myotis septentrionalis	3	0	1	1	1
Wentz	I	7/20/2007	*Eptesicus fuscus*	9	0	2	6	1
			Lasiurus borealis	1	1	0	0	0
			Myotis lucifugus	1	1	0	0	0
			Myotis septentrionalis	8	0	3	3	2
			Myotis sodalis	1	0	0	1	0
Wentz	I	7/23/2007	*Eptesicus fuscus*	11	4	1	2	4
			Lasiurus borealis	1	0	0	0	1
			Myotis septentrionalis	2	1	0	1	
Wentz	H	7/24/2007	*Eptesicus fuscus*	7	1	0	3	3
			Lasiurus borealis	1	0	0	0	1

Table 1 continued.

Area	Site no.	Date	Species	No. captures*	Male A	Male J	Female A	Female J
			Myotis lucifugus	2	0	0	1	1
			Myotis septentrionalis	1	0	0	0	1
			Myotis sodalis	1	0	0	1	0
Wentz	I	7/25/2007	*Eptesicus fuscus*	8	2	1	2	2
			Myotis septentrionalis	1	0	0	1	0
Wentz	H	7/26/2007	*Eptesicus fuscus*	15	7	4	4	0
			Lasiurus borealis	4	3	0	0	1
			Myotis lucifugus	2	2	0	0	0
Wentz	I	7/27/2007	*Eptesicus fuscus*	1	0	1	0	0
			Myotis lucifugus	1	0	0	0	1
			Myotis septentrionalis	1	0	0	1	0
Taneytown	C	8/2/2007	*Eptesicus fuscus*	3	0	0	3	0
			Lasiurus borealis	2	0	1	0	1
			Myotis lucifugus	6	0	0	4	1
			Myotis septentrionalis	1	1	0	0	0
Taneytown	J	8/3/2007	*Eptesicus fuscus*	1	0	0	1	0
			Myotis lucifugus	12	0	1	5	6
			Perimyotis subflavus	2	0	0	0	2
Taneytown	E	8/6/2007	*Eptesicus fuscus*	2	2	0	0	0
			Lasiurus borealis	4	0	0	3	1
			Myotis lucifugus	14	2	1	8	3
			Myotis septentrionalis	2	0	0	2	0
			Perimyotis subflavus	1	0	0	0	1
Taneytown	D	8/7/2007	*Lasiurus borealis*	1	1	0	0	0
			Myotis sodalis	1	0	1	0	0
Taneytown	K	8/8/2007	No captures	–	–	–	–	–
Taneytown	F	8/10/2007	*Lasiurus borealis*	2	0	1	0	1
			Myotis lucifugus	3	1	1	1	0
Hashawha	L	8/13/2007	*Eptesicus fuscus*	1	0	0	1	0
			Lasiurus borealis	4	0	0	2	1
Hashawha	M	8/14/2007	*Eptesicus fuscus*	1	1	0	0	0
			Lasiurus borealis	1	0	0	1	0
			Myotis lucifugus	2	1	0	1	0
			Perimyotis subflavus	1	0	0	0	1
Hashawha	A	8/15/2007	*Eptesicus fuscus*	1	1	0	0	0
			Lasiurus borealis	3	1	1	0	1
			Lasiurus cinereus	1	1	0	0	0
			Myotis lucifugus	2	2	0	0	0
Hashawha	B	8/16/2007	*Eptesicus fuscus*	2	0	0	1	1
			Myotis lucifugus	2	1	0	0	1
Total			*Eptesicus fuscus*	127	32	25	47	19
			Lasiurus borealis	40	13	5	9	11
			Lasiurus cinereus	2	1	1	0	0
			Myotis lucifugus	184	18	22	95	47
			Myotis septentrionalis	38	2	8	21	7
			Myotis sodalis	3	0	1	2	0
			Perimyotis subflavus	9	2	0	3	4

* Discrepancies between total number of bats captured and sum of males and females are because bats escaped before sex was determined.

Table 2. Number of bats captured per unit effort [no. captures/(mist net surface area × number of hours open)] in Carroll County, Maryland, July–August 2007.

Area	Date	Site no.	Net nights[a]	Net hours[b]	*Eptesicus fuscus*	*Lasiurus borealis*	*Lasiurus cinereus*	*Myotis lucifugus*	*Myotis septentrionalis*	*Myotis sodalis*	*Perimyotis subflavus*	All species
Hashawha	7/2/2007	A	6	507.0	–	0.0079	–	0.0039	0.0020	–	0.0010	0.0237
Hashawha	7/3/2007	B	7	975.0	0.0062	0.0021	–	0.0031	0.0062	–	–	0.0174
Hashawha	7/6/2007	A	6	507.0	0.0020	0.0020	–	0.0079	–	–	–	0.0118
Hashawha	7/9/2007	B	8	878.7	0.0057	0.0011	–	0.0102	–	–	–	0.0171
Taneytown	7/10/2007	C	6	702.0	0.0085	0.0028	–	0.0627	–	–	–	0.0741
Taneytown	7/12/2007	D	6	858.0	0.0093	0.0012	–	0.0128	–	–	–	0.0233
Taneytown	7/13/2007	E	6	819.0	0.0037	0.0012	–	0.0476	0.0073	–	–	0.0598
Taneytown	7/16/2007	F	5	741.0	0.0094	0.0013	0.0013	0.0310	0.0040	–	–	0.0432
Wentz	7/17/2007	G	4	312.0	0.0128	–	–	–	–	–	–	0.0128
Wentz	7/18/2007	G	5	624.0	0.0048	0.0016	–	0.0016	0.0048	–	–	0.0128
Wentz	7/19/2007	H	6	858.0	0.0256	0.0023	–	0.0012	0.0035	–	–	0.0326
Wentz	7/20/2007	I	6	546.0	0.0165	0.0018	–	0.0018	0.0147	0.0018	–	0.0366
Wentz	7/23/2007	I	5	507.0	0.0217	0.0020	–	–	0.0039	–	–	0.0276
Wentz	7/24/2007	H	7	871.5	0.0080	0.0011	–	0.0023	0.0011	0.0011	–	0.0138
Wentz	7/25/2007	I	4	351.0	0.0023	–	–	–	0.0028	–	–	0.0256
Wentz	7/26/2007	H	7	975.0	0.0154	0.0041	–	0.0021	–	–	–	0.0215
Wentz	7/27/2007	I	5	468.0	0.0021	–	–	0.0021	0.0021	–	–	0.0064
Taneytown	8/2/2007	C	5	624.0	0.0048	0.0032	–	0.0096	0.0016	–	–	0.0192
Taneytown	8/3/2007	J	4	624.0	0.0016	–	–	0.0192	–	–	0.0032	0.0240
Taneytown	8/6/2007	E	4	507.0	0.0039	0.0079	–	0.0276	0.0039	–	0.0020	0.0454
Taneytown	8/7/2007	D	4	624.0	–	0.0016	–	–	–	0.0016	–	0.0032

Table 2. Continued

Area	Date	Site no.	Net nights[a]	Net hours[b]	*Eptesicus fuscus*	*Lasiurus borealis*	*Lasiurus cinereus*	*Myotis lucifugus*	*Myotis septentrionalis*	*Myotis sodalis*	*Perimyotis subflavus*	All species
Taneytown	8/8/2007	K	3	35.1	–	–	–	–	–	–	–	–
Taneytown	8/10/2007	F	5	741.0	–	0.0027	–	0.0040	–	–	–	0.0067
Hashawha	8/13/2007	L	6	702.0	0.0014	0.0057	–	–	–	–	–	0.0071
Hashawha	8/14/2007	M	6	663.0	0.0015	0.0015	–	0.0030	–	–	0.0015	0.0075
Hashawha	8/15/2007	A	6	507.0	0.0020	0.0059	0.0020	0.0039	–	–	–	0.0138
Hashawha	8/16/2007	B	4	624.0	0.0032	–	–	0.0032	–	–	–	0.0064
Total			146	17151.3	0.0074	0.0023	0.0001	0.0107	0.0022	0.0002	0.0005	0.0235

a Net nights = number of mist nets and harp traps opened.

b Net hours = total surface area of mist nets (m2) × number of hours open.

Table 3. Bat echolocation passes recorded by Anabat II bat detector in Carroll County, Maryland, July–August 2007.

Area	Site no.	Date	Time First pass	Total passes Last pass	Speciesa Total (hr)		NOID	EPFU	LABO	LACI	MYLU	MYSE	MYSO	MYsp	PESU
Hashawha	A	7/2/2007	2047.25	0141.15	4.90	496	40	0	0	0	35	4	0	158	259
Hashawha	B	7/3/2007	2034.48	0130.51	4.95	128	20	8	12	2	30	3	0	7	46
Hashawha	A	7/6/2007	2047.02	0124.38	4.63	628	162	10	164	0	152	2	0	119	19
Hashawha	B	7/9/2007	2040.58	0139.59	4.98	161	28	37	33	0	23	6	0	33	1
Taneytown	C	7/10/2007	2039.05	0142.13	5.05	1,216	43	109	5	1	1,027	0	0	25	6
Taneytown	D	7/12/2007	2041.22	0135.07	4.90	678	41	14	0	0	376	4	0	243	0
Taneytown	E	7/13/2007	2036.51	0140.55	5.07	775	74	35	33	0	557	4	3	49	20
Taneytown	F	7/16/2007	2048.27	0136.43	4.80	780	145	57	16	1	494	1	0	60	6
Wentz	G	7/17/2007	2041.52	0133.28	4.86	557	82	353	80	36	0	1	0	2	3
Wentz	G	7/18/2007	2049.41	0130.30	4.68	369	43	286	22	3	7	3	1	1	3
Wentz	H	7/19/2007	2041.15	0125.36	4.74	967	194	413	91	7	207	6	7	19	23
Wentz	I	7/20/2007	2053.42	0201.58	5.13	286	31	234	2	0	0	15	1	2	1
Wentz	I	7/23/2007	2057.59	2316.28	3.31	158	19	130	7	0	0	1	0	1	0
Wentz	H	7/24/2007	2032.51	0217.29	5.74	753	128	299	101	0	117	3	0	87	18
Wentz	I	7/25/2007	2030.58	0131.59	5.52	190	71	82	30	0	1	5	0	1	0
Wentz	H	7/26/2007	2034.11	0201.47	5.46	651	124	275	93	0	70	1	2	47	39
Wentz	I	7/27/2007	2040.01	0143.26	5.06	248	71	162	15	0	0	0	0	0	0
Taneytown	C	8/2/2007	2013.15	0120.32	5.12	981	47	82	2	0	790	1	1	40	18
Taneytown	C	8/3/2007	2020.56	0103.13	4.70	857	23	85	4	0	706	2	4	26	7
Taneytown	E	8/6/2007	2020.25	0110.05	4.83	1,182	34	77	0	0	1,042	0	4	10	15
Taneytown	D	8/7/2007	2020.00	0114.41	4.91	764	46	11	4	0	310	1	91	287	14
Taneytown	F	8/10/2007	2021.39	0109.49	4.80	817	140	29	8	0	530	0	0	98	12
Hashawha	L	8/13/2007	2008.42	0109.12	5.01	429	60	214	62	0	8	0	0	10	75
Hashawha	M	8/14/2007	2013.55	0106.30	5.38	785	39	20	5	0	589	0	0	109	23
Hashawha	A	8/15/2007	2006.07	0056.36	4.84	537	126	30	2	0	311	1	0	42	25
Hashawha	B	8/16/2007	2001.01	0057.05	4.93	142	11	17	33	0	50	1	0	7	23
Total					128.30	15,535	1,842	3,069	824	50	7,432	65	114	1,483	656

a NOID = Unidentifiable bat pass; EPFU = *Eptesicus fuscus*; LABO = *Lasiurus borealis*; LACI = *Lasiurus cinereus*; MYLU = *Myotis lucifugus;* MYSE = *Myotis septentrionalis*; MYSO = *Myotis sodalis*; MYsp = *Myotis spp.*; PESU = *Perimyotis subflavus.*

days; all locations were in the same area near a small pond and transmission line corridor. It is unclear if the bat was roosting in different trees each day, or if our triangulations were slightly different each day, resulting in perceived different roost trees. There were several snags in and adjacent to the small pond, which was adjacent to a 13.4 ha woodlot, likely comprised of oaks and hickories, similar to surrounding woodlots. The geometric mean of the three triangulations was approximately 340 m from the capture site. We documented two roost trees used by the juvenile male Indiana myotis on private property; one in a 3 ha woodlot and one adjacent to a county road. The two roost trees were 2.6 and 2.1 km, respectively, from where the bat was captured on Big Pipe Creek. The trees were 535 m apart and both were American elm (*Ulmus americana*) snags with exfoliating bark under which the bat(s) was roosting. We conducted an exit count at both roost trees. We observed six bats (including the tagged bat) emerging from under exfoliating bark on the bole (height = 4.5 m) and upper limbs (height = 25.0 m) of the roost tree in the woodlot, and one bat (the tagged bat) emerging from under exfoliating bark on the upper limbs (height = 10.5 m) of the roost tree located adjacent to the county road. The height and

Table 4. Distance-based habitat use analysis between female *Myotis sodalis* (n = 1) foraging locations (n = 81) and random locations (n = 81) in Carroll County, Maryland, July 2007.

Variable	Foraging location		Random location		*P*
	Mean[a]	SE	Mean	SE	
Developed	751.0A	13.8	616.1	25.3	<0.001
Paved roads	369.7B	13.6	198.0	14.9	<0.001
Water	84.0C	10.9	238.8	15.3	<0.001
Field	34.5D	3.2	21.1	4.9	<0.001
Forest	7.6E	2.1	59.5	8.8	<0.001

[a]Distances (m). Tests were performed on ranked data, actual values are shown. Means followed by different letters differ as determined by Duncan's New Multiple Range Test.

Table 5. Distance-based habitat use analysis between male *Myotis sodalis* (n = 1) foraging locations (n = 33) and random locations (n = 33) in Carroll County, Maryland, August 2007.

Variable	Foraging location		Random location		*P*
	Mean[a]	SE	Mean	SE	
Developed	523.1A	42.8	441.7	42.7	0.171
Paved roads	203.6B	27.5	221.8	28.5	0.549
Water	140.2BC	16.1	179.7	23.8	0.386
Forest	109.2C	13.9	160.8	24.7	0.229
Field	3.3D	1.5	4.0	1.7	0.463

[a]Distances (m). Tests were performed on ranked data, actual values are shown. Means followed by different letters differ as determined by Duncan's New Multiple Range Test.

DBH of the roost tree in the woodlot was 35.0 m and 72.4 cm, respectively. The mean height and DBH of surrounding trees was 8.8 m ($n = 27$, SE ± 1.1, range 3.0–26.0) and 12.7 cm ($n = 27$, SE ± 1.8, range 5.1–39.5). The distance from the roost tree to the nearest codominant tree was 6.4 m. The surrounding tree species included American elm, shagbark hickory, hawthorn (*Crataegus* sp.), and white oak (*Quercus alba*). The surrounding area (i.e., woodlot) was level and had sparse understory vegetation. The roost tree adjacent to the county road was multi-trunked, separating near ground level. The height and DBH of the roost tree was 17.5 m and 45.2 cm, respectively. The mean height and DBH of surrounding trees (including boles in the multi-trunked tree) was 13.0 m ($n = 9$, SE ± 0.9, range 10.0–16.0) and 27.4 cm ($n = 9$, SE ± 3.8, range 13.2–45.7). The distance from the roost tree to the nearest codominant tree was less than 1 m. The surrounding tree species included American elm and red maple (*Acer rubrum*). The roost tree was located in a tree line between the county road and a hayfield.

We were able to determine only three foraging locations of the Indiana myotis captured on 21 July despite extensive searching within 2 km of the capture site for four nights subsequent to tagging. We located the Indiana myotis captured on 24 July 81 times during four nights while it was foraging. Mean foraging distance from the geometric mean of the three roost locations was 217.5 m ($n = 81$, SE ± 14.9, range 22.5–790.1). Home range sizes for 50, 75, and 95% confidence intervals were 5.2, 11.9, and 31.5 ha, respectively. Compared to random locations, this bat foraged closer to forested areas and water sources and farther from fields, roads, and developed areas (Table 4). Moreover, among all land cover types, the bat foraged closer to forested areas. We determined foraging locations of the juvenile male Indiana myotis 33 times during two nights. Mean foraging distance from the geometric mean of the two roost locations was 1,075.3 m ($n = 33$, SE ± 109.9, range 150.3–2,498.1). Home range sizes for 50, 75, and 95% confidence intervals were 78.7, 202.2, and 425.4 ha, respectively. Compared to random locations, this bat did not forage closer to any land cover types (Table 5). However, among land cover types, it foraged closer to fields than forested areas, water sources, roads, and developed areas.

Discussion

The species composition we documented in northern Carroll County is similar to that which has been recorded by other bat inventories in the Piedmont province of Maryland and Pennsylvania with the exception of Indiana myotis, which has only recently been documented in the Piedmont during summer (Butchkoski & Turner 2005; Hart 2006; Johnson et al. 2008). Our capture rates far exceeded those of other bat inventories in the area, probably as a result of serendipitously mist netting near maternity colonies (Hart 2006; Johnson et al. 2008). The highly fragmented forest cover in the area may limit roosting opportunities and concentrate bats in areas with forest cover, especially those near water sources (e.g., Big Pipe Creek; Carter 2006). Acoustic monitoring also recorded high bat activity levels. Indiana myotis were acoustically recorded only in areas where they had been physically documented, either in 2005 or during this study. These results, in addition to our mist net results, confirm that Indiana myotis remain in the Wentz and Taneytown areas during the maternity season. No Indiana myotis were captured or acoustically recorded at Hashawha, although the habitat there is similar to that in the Taneytown and Wentz areas, indicating that Indiana myotis potentially could

occur there. Large shagbark hickory trees and snags of various species, and permanent water sources occurred in all the areas we surveyed. Throughout their range, female Indiana myotis form maternity colonies in primary roost trees, which typically are large-diameter (>35 cm) dead trees with direct exposure to sunlight (Humphrey et al. 1977; Kurta et al. 1993a, b; Callahan et al. 1997; Britzke et al. 2003). Indeed, the roost trees that we documented were either on forest edges or in canopy gaps where there was increased solar exposure. However, we were unable to conclusively determine if any of the roost trees we documented were primary roost trees being used by maternity colonies. The exit counts at the two roost trees in which the juvenile male Indiana myotis roosted resulted in counts of one and six individuals, including the tagged bat. It is unclear if all the bats roosting in the trees were Indiana myotis. Moreover, it is unclear if the six bats using one of the trees formed a maternity colony because Indiana myotis are known to disband during the first half of August. However, they may persist and steadily decline into mid-September (Humphrey et al. 1977; Kurta et al. 1993b). We were unable to gain access to one private property in order to conduct exit counts at roost trees documented in 2005 or even locate specific trees in which one of the Indiana myotis we captured was roosting. However, it is likely the bat was roosting in one of several snags in or near a small pond. In the Midwest, it is common for Indiana myotis to form maternity colonies in snags in wetlands where there is direct solar exposure (Kurta et al. 2002).

Indiana myotis may or may not return to the same roost trees year after year (Kurta & Murray 2002; Kurta et al. 2002; Britzke et al. 2003). We did not document any bats roosting in a mockernut hickory that was used by Indiana myotis in 2005. That is not to say that this tree is no longer being used as a roost, as Indiana myotis are known to move short distances (<6 km) to other roost trees every two to three days (i.e., we could have examined the tree shortly before or after Indiana myotis roosted there; Gumbert et al. 2002; Kurta et al. 2002). We observed bats emerging from shagbark hickory trees that were used by Indiana myotis in 2005, but were unable to determine the species of the bats. We did not capture any Indiana myotis over Big Pipe Creek, which was greater then 100 m from the trees, but did capture little brown myotis and northern myotis that may have been using the trees as roost sites. It is possible that Indiana myotis continue to use this tree and other trees in the vicinity as roost sites. In addition to the primary roost trees Indiana myotis use, they also use alternate or secondary roost trees, which commonly are shaded live trees, during elevated precipitation or temperature events (Callahan et al. 1997). None of the roost trees that we documented fit the description of a secondary roost tree, but surely these alternate roost trees exist within the forest fragments in the area. Although we documented no Indiana myotis using bat boxes or anthropogenic structures (i.e., barns), they have been recorded using bat boxes and structures in Indiana and Pennsylvania (Butchkoski & Hassinger 2002; Ritzi et al. 2005).

The foraging behavior of the Indiana myotis we radio-tracked differed from those documented in the Midwest. The juvenile male we radio-tracked had a larger home range than those documented in other studies (Menzel et al. 2005). Conversely, the female for which we were able to determine a home range foraged in a smaller area than those recorded in other studies (Menzel et al. 2005; Watrous et al. 2006). Maximum foraging distances we recorded for the male and female Indiana myotis were less than those

reported in the Midwest (Murray & Kurta 2004; Sparks et al. 2005). In Missouri, the maximum recorded distances that male and female Indiana myotis foraged from their roosts were 2.5 km and 6.1 km, respectively, and had mean home ranges of 255 ha and 113 ha, respectively, based on 90% minimum convex polygon analysis (Rommé et al. 2002). In Illinois, male and female Indiana myotis had mean home ranges of 144.7 ha and 161.1 ha, respectively, based on 95% adaptive kernel methods (Menzel et al. 2005). In Pennsylvania, male and female Indiana myotis had home ranges of 39 to 112 ha, where they spent most (>50%) of their foraging time (Butchkoski & Hassinger 2002). It is unclear exactly why the female we radio-tracked had a relatively small home range. The small forest fragments in the immediate area and its preference for foraging within forests may have resulted in this bat having a small home range. Perhaps this bat was able to fulfill its requirements (i.e., roost sites, water, and insect prey) within this small area, thus making a larger home range unnecessary. It is unclear why the juvenile male we radio tracked had a relatively large home range. This bat may have been attempting to establish successful foraging areas, although little is known about how bats initially learn to forage and establish a home range (Buchler 1980; Brigham & Brigham 1989). Buchler (1980) observed the initial flights of juvenile little brown myotis and determined that they foraged separately from adults to avoid acoustic interference. Also, they foraged in open areas and along tree lines, probably because they were weak flyers and less maneuverable at an early age. Adams (1996, 1997) observed similar behavior in juvenile little brown myotis in Wyoming. Juvenile bats foraged in open areas, whereas adults shifted their foraging patterns from open areas to more cluttered forest interiors as more juveniles became volant. This may partially explain why the juvenile male bat we radio-tracked foraged closer to fields than other cover types. A qualitative examination of its foraging locations on an aerial image showed that it foraged along tree lines separating agricultural fields. In Michigan, Indiana myotis used wooded corridors even though doing so increased commuting distances (Murray & Kurta 2004). Bats may exploit linear landscape elements that provide cover from predators, orientation cues, and windbreaks where insects concentrate (Lewis 1966; Limpens & Kapteyn 1991).

The foraging behavior of the female Indiana myotis we radio-tracked was similar to that documented in studies throughout the range of the Indiana myotis. Typically, Indiana myotis forage in forested areas in upland and riparian settings (Humphrey et al. 1977; LaVal et al. 1977; LaVal & LaVal 1980; Brack 1983; Ford et al. 2005). Indiana myotis preferentially foraged in wooded areas rather than developed areas at a rural-urban interface in Indiana (Sparks et al. 2005). In West Virginia, Indiana myotis activity was higher in intact forest cover than in forest gaps (Ford et al. 2005). Radio-tagged bats from a maternity colony in Pennsylvania were documented foraging mostly in a nearby section of intact forest with relatively flat (<10° slope) topography (Butchkoski & Hassinger 2002). In Illinois, Indiana myotis foraged closer to forests and riparian habitats than agricultural lands (Menzel et al. 2005). Carter (2006) emphasized the importance of maintaining riparian habitats to the conservation of Indiana myotis as maternity colonies occur more frequently in riparian zones than upland sites. These locations commonly are characterized by an abundance of large diameter trees, snags, and insect prey. Furthermore, conversion of upland forests to agricultural use may restrict the bats to riparian zones.

Further research examining the distribution of Indiana myotis on the Piedmont and possibly the Coastal Plain of Maryland is warranted. These areas are within migration distances of Indiana myotis and may contain habitat for Indiana myotis. The oak-hickory forests and low gradient riparian corridors on the Piedmont probably are similar to conditions that occur in the core of the Indiana myotis distribution range in the Midwest (Carter et al. 2002; Farmer et al. 2002; Gardner & Cook 2002; Miller et al. 2002; Menzel et al. 2005). These habitat features also may exist on the Coastal Plain, creating the possibility that Indiana myotis may occur there.

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The Terrestrial Ecology of an Allegheny Amphibian Community: Implications for Land Management

Walter E. Meshaka, Jr.[1]

[1]Section of Zoology and Botany, State Museum of Pennsylvania, 300 North Street, Harrisburg, PA 17120, USA

Abstract- A two-year standardized collection of terrestrially active amphibians was conducted in primarily forested habitat at the Powdermill Nature Reserve (PNR) in the Allegheny front of western Pennsylvania. The American Toad *(Anaxyrus americanus)* and the Allegheny Dusky Salamander *(Desmognathus ochrophaeus)* were the most frequently trapped of the 18 species. Most of the species in this study were strongly associated with forests, and grassland was the least productive habitat for any of the frogs, toads, and salamanders. The combination of these baseline ecological data, the protected nature of the study site, and the similarity of the amphibian community to much of the northern Allegheny Mountains provide information regarding amphibian community dynamics in older forests and timing of potentially lethal forest management techniques. In turn, these baseline data provide the opportunity to test community-wide responses to forest management with benchmarks at both PNR and other protected sites across the northern Allegheny Mountains.

Powdermill Nature Reserve (PNR) is an 856.2 ha field station located in the Ligonier Valley of the Allegheny Mountains in Westmoreland County of western Pennsylvania. First outlined in 1948 and established in 1956 by then Assistant Director of the Carnegie Museum of Natural History, Dr. M. Graham Netting, PNR consists of mix forests, fields, ponds and streams, and serves as a field station for the Carnegie Museum amenable for longterm study of natural systems and their components. The location of the station is within the geographic distributions of many amphibian species (Conant and Collins, 2002; Hulse et al., 2001). A large number of specimens systematically collected at the PNR from 1982 to 1983 provided the opportunity to examine habitat associations, seasonal activity, growth, and in some cases, reproduction of 18 amphibian species.

The goal of this project was to provide ecological data on terrestrially active amphibians in the protected system of older forests and grasslands of PNR. Data on terrestrial active amphibians can be used to identify the safest timing for potentially lethal forest management techniques and for setting benchmarks for forest management programs at PNR and elsewhere in the upper Allegheny Mountain range with similar amphibian faunas.

Materials and Methods

During April to October of 1982 and 1983, 66 arrays were set at seven sites on PNR property. Each array consisted of a single 1.8-2.4 m drift fence, which bisected an 11.4 L coffee can at each end. The cans were filled with formalin to a few inches in

 [1]wmeshaka@state.pa.us

depth and checked each week. All animals collected in the trap were deposited in the Carnegie Museum of Natural History.

Eight traps at the Byer site were set in mixed deciduous forest adjoining a creek. Traps at this site were checked during 1982. The eight traps at the Calverly site were set in mixed deciduous forest adjoining a creek. Traps at this site were checked during 1982. The nine traps at the Friedline site were set in open field far from standing or running water. Traps at this site were checked during 1982. The 10 traps at the Leberman Cabin site were set in very wet deciduous forest, and ponds were in the vicinity of this site. Traps at this site were checked during 1982. The four traps at the Middle Strip Mine site were set in mixed deciduous forest and not near any creek. Traps at this site were checked during 1982. The 11 traps at the Along Strip Mine Road site were set along the roadside in primarily mixed deciduous forest. At the lowest elevation, traps began just after a pond and continued to the top of the road and in part along a creek. Traps at this site were checked during 1983. The 16 traps at the Southeast Weaver Mill site were set in the same primarily mixed deciduous forest as those of the Along Strip Mine Road site. These traps ran roughly parallel to the previous site in the forest and some interfaced with the same creek as did traps from Along Strip Mine Road site. Traps at this site were checked during 1983.

Raw data from species captures as a percentage of the total number of amphibian captures were used to measure terrestrial amphibian community structure. Habitat association was determined using numbers of animals per trap so as to correct for uneven numbers of traps among sites. Seasonal activity was determined by assembling all data for both years in a single monthly bar histogram. Growth rates were estimated and emergence times were identified by comparing monthly length-frequency histograms of body sizes measured in mm snout-vent length (SVL). The April-October datasets were presented in these figures with all months present to more easily identify cohorts. In some instances, only a subset of individuals was measured for use in body size distributions. Reproductive data were available for some of the species, especially the Allegheny Dusky Salamander *(Desmognathus ochrophaeus)*, and were presented in the species accounts. Common and Scientific names followed the arrangement of Collins and Taggart (2002).

Results

The Amphibian Community- Although the number of species captured was highest at the Calverly site, the numbers of individuals captured per trap were highest at the Along Strip Mine Road site (Table 1). Comparatively, the grassland habitat of the Friedline site had the fewest individual captures per trap. For the amphibian community, seasonal activity was unimodal, greatest during July-September, with a seasonal peak in August (Figure 1).

Table 1. Relative abundance of amphibians as measured by numbers of individuals captured/trap along seven transects at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

Species	Byer, 1982	Calverly 1982	Friedline 1982	Leberman Cabin 1982	Middle Strip Mine 1982	Along Strip Mine Road 1983	Southeast Weaver Mill 1983
A. americanus	3.38	12.25	1.78	37.1	12	57.00	30.06
L. catesbeianus	0	0	0	0	0	0.09	0
L. clamitans	0.13	0.13	0.33	7.2	4	4.91	2
L. palustris	0.13	2.38	0.22	3.7	2	1.27	0.31
L. sylvaticus	0.13	3.8	0.33	4.3	6	3.73	2.44
P. crucifer	0.13	0.13	0	5	2	0.27	0
D. fuscus	0	0.13	0	0.9	0.25	1.73	0.06
D. monticola	0.13	0.13	0	0	0	0	0
D. ochrophaeus	10.25	11.13	0.22	12.8	2.25	39.18	19.13
E. bislineata	0.13	0.5	0	0.2	0	0.18	0.06
E. longicauda	0	0.13	0	0	0	0	0
G. porphyriticus	0.38	0.63	0	0.6	0	0.82	0.31
H. scutatum	0	0	0	0.1	0	0	0.06
N. viridescens	0.13	0.63	0	6.9	3.3	0.09	0.82
P. cinereus	4	1.13	0.56	3.9	3.5	5.18	2.75
P. glutinosus	2.88	1.5	0	0.1	2	3.18	1.63
P. wehrlei	0	0.13	0	0	0.25	0.55	0
P. ruber	0	0.25	0	0.1	0.25	0	0
No. frog and toad species	5	5	4	5	5	6	5
No. salamander species	7	11	2	9	7	8	8
Total no. species	12	16	6	14	12	14	13
No. traps	8	8	9	10	4	11	16
No. individuals/trap	22.75	36	3.44	82.9	37.75	118.18	59.63

SPECIES ACCOUNT

Anura

Bufonidae

Anaxyrus americanus (Holbrook, 1836)- The American Toad comprised 44.66% of all amphibian captures with 1,668 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Along Strip Mine Road site, but toads were present at all sites (Table 1). Individuals were active during April-October, most active during July-September, and the numbers of juveniles increased steadily through the season as appearance of metamorphs leveled off during July to August (Figures 4 and 5). For both years combined, metamorphs were captured during May to August, when juveniles dominated the collections (Figures 4 and 5). The seasonal distribution of body sizes suggested that sexual maturity could have been reached before

Figure 1. Seasonal activity of 18 amphibian species at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

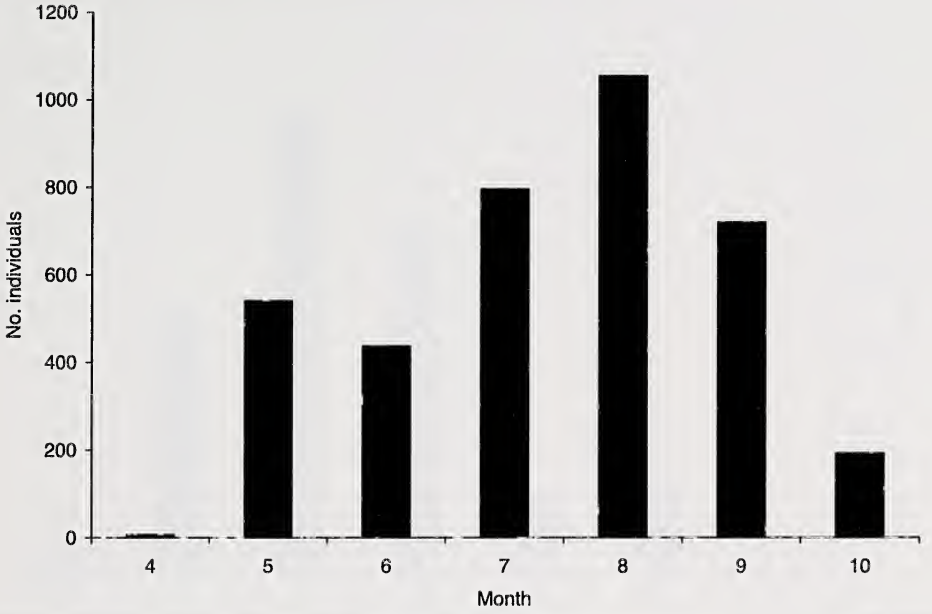


Figure 2. Community structure of 18 amphibian species at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

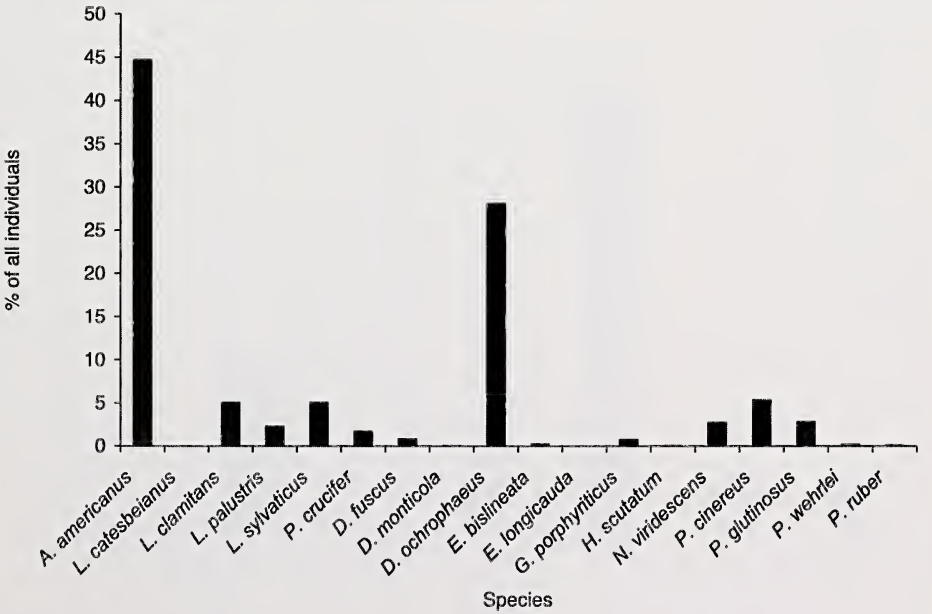


Figure 3. Seasonal activity of the American Toad *(Anaxyrus americanus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

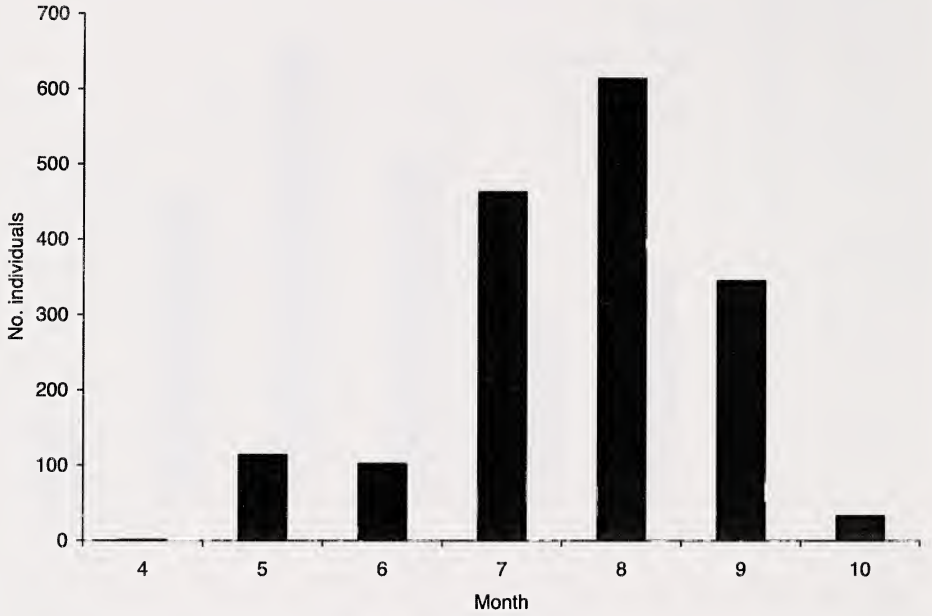


Figure 4. Seasonal distribution of body size of the American Toad *(Anaxyrus americanus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, in 1982.

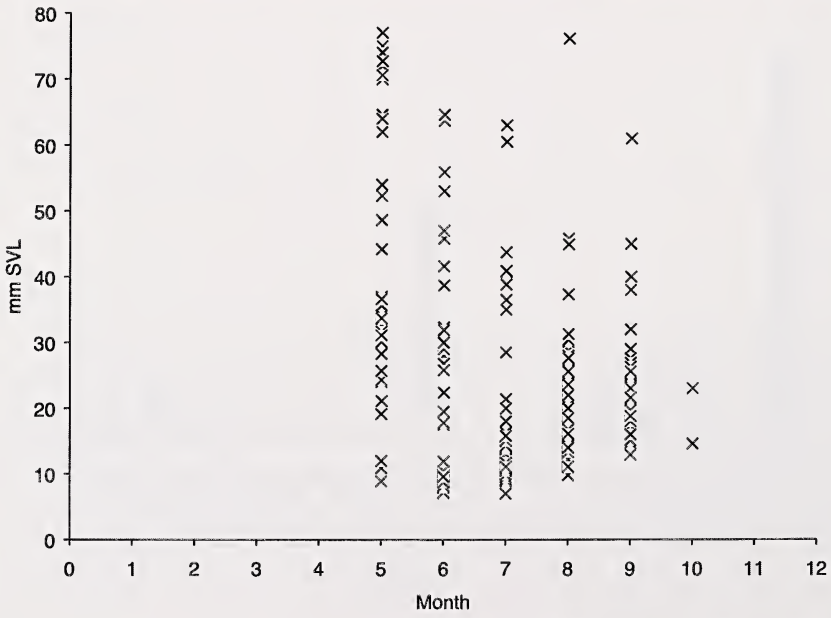


Figure 5. Seasonal distribution of body size of the American Toad *(Anaxyrus americanus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, in 1983.

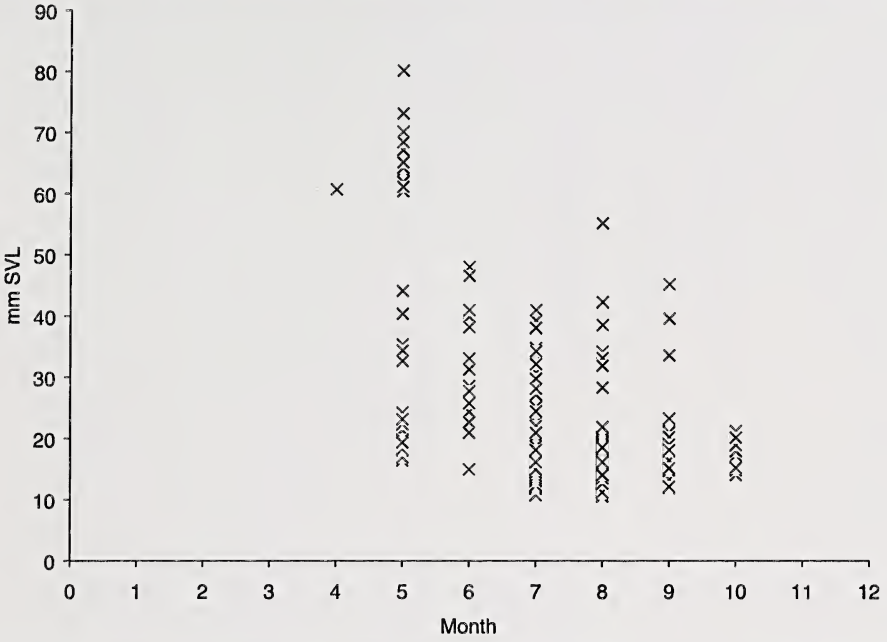


Figure 6. Seasonal activity of the Spring Peeper *(Pseudacris crucifer)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

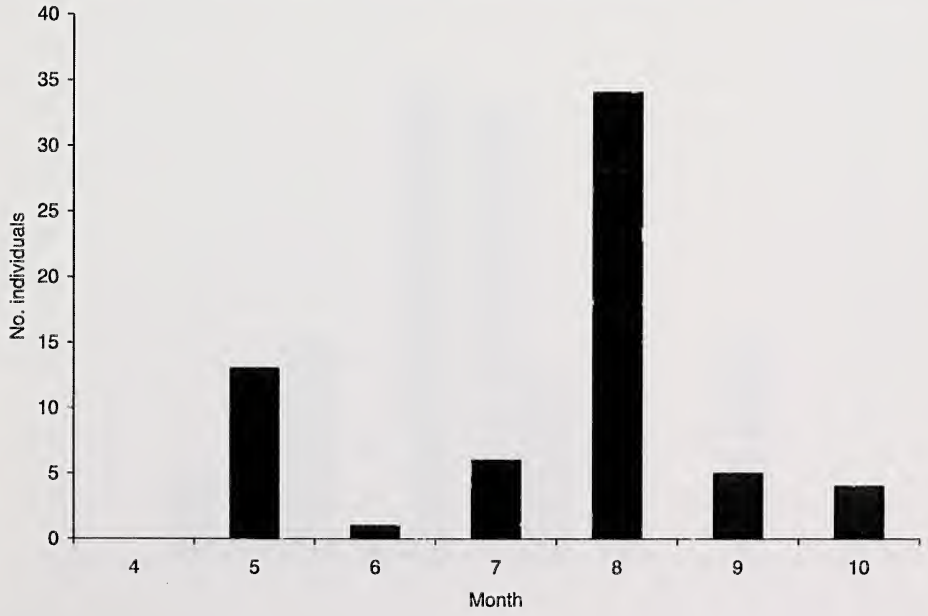


Figure 7. Seasonal distribution of body sizes of the Spring Peeper *(Pseudacris crucifer)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

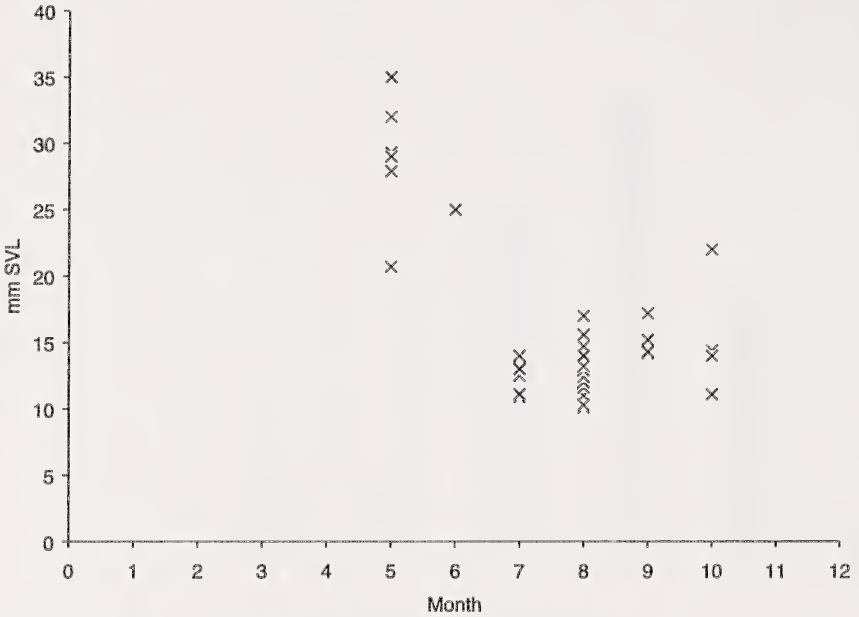


Figure 8. Seasonal activity of the Green Frog *(Lithobates clamitans)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

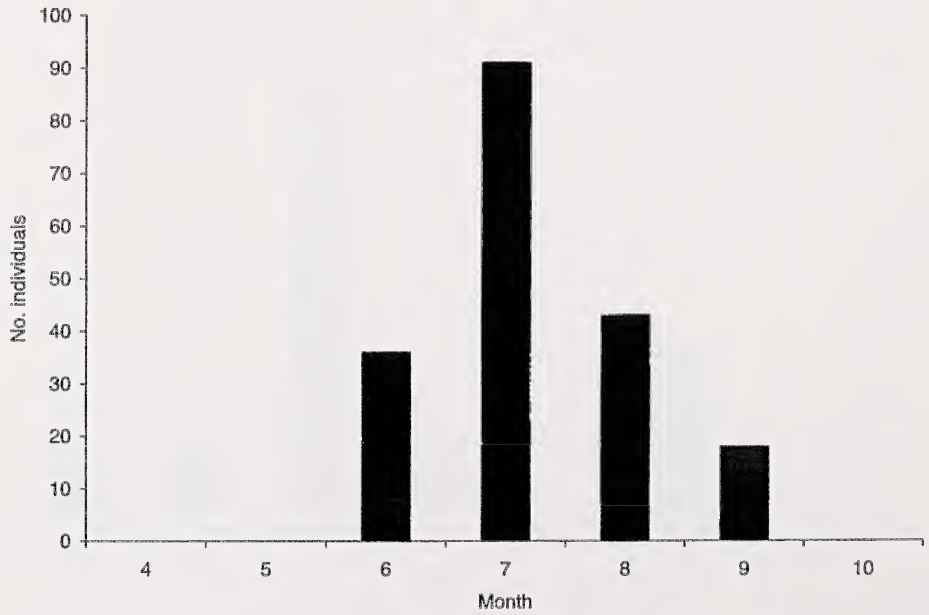


Figure 9. Seasonal distribution of body sizes of the Green Frog *(Lithobates clamitans)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

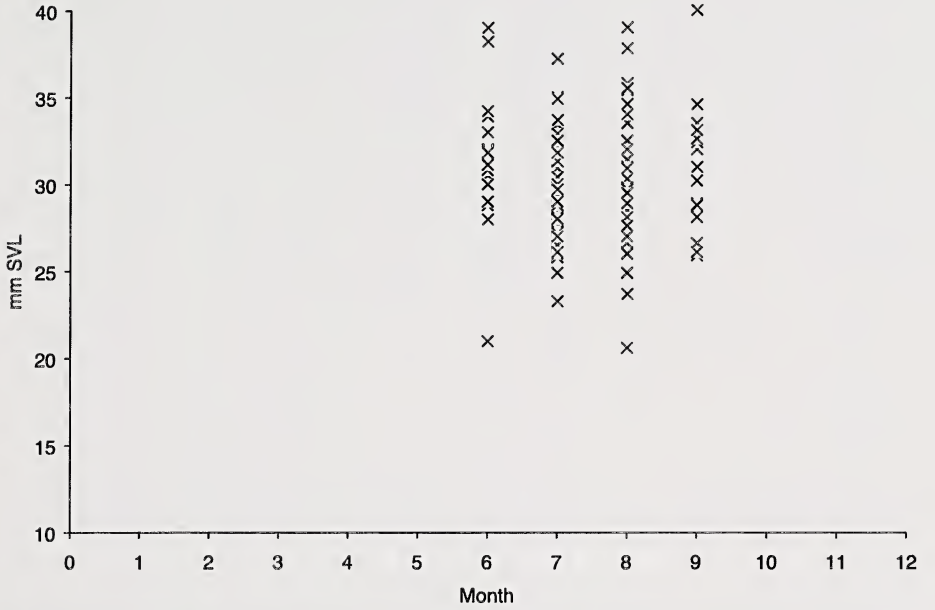


Figure 10. Seasonal activity of the Pickerel Frog *(Lithobates palustris)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

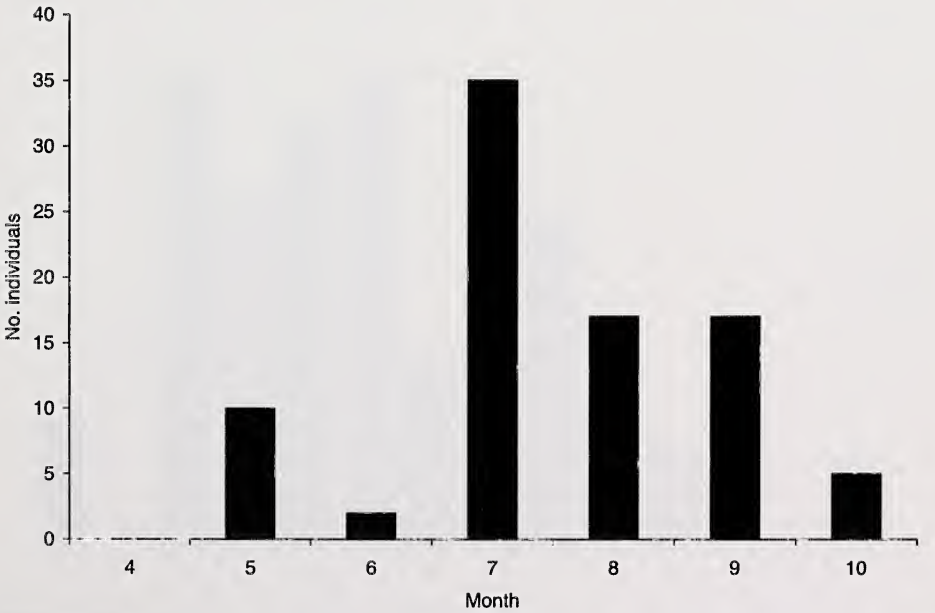


Figure 11. Seasonal distribution of body size of the Pickerel Frog *(Lithobates palustris)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

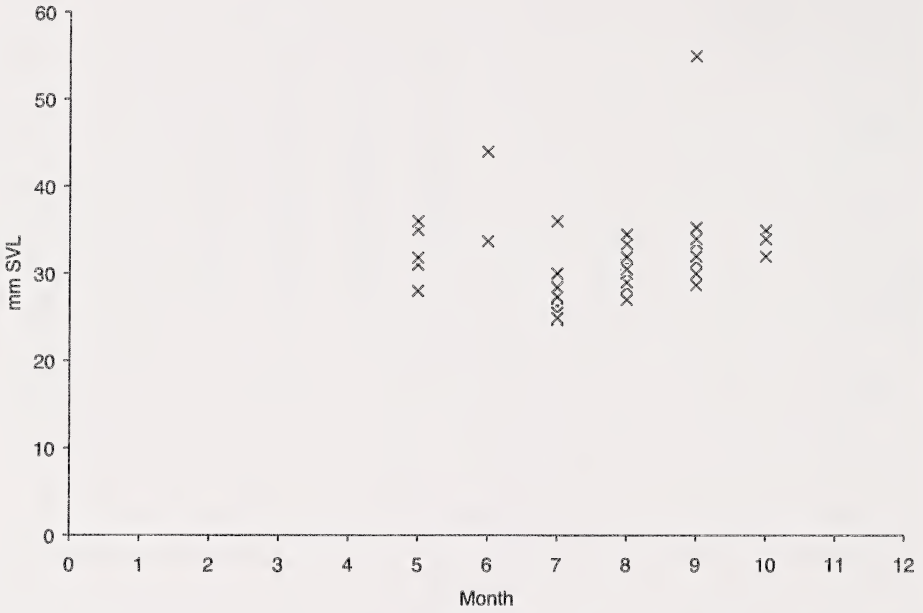


Figure 12. Seasonal activity of the Wood Frog *(Lithobates sylvaticus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

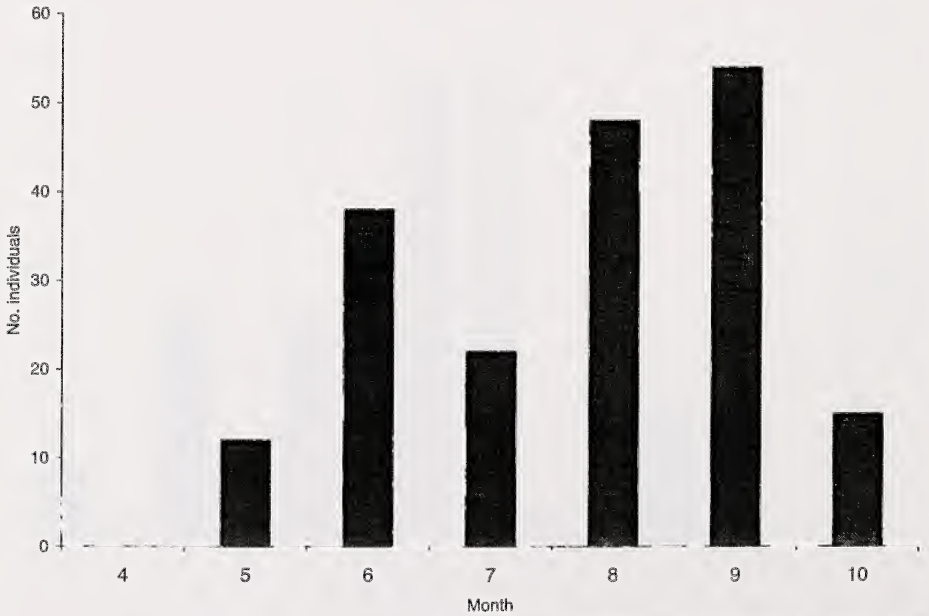


Figure 13. Seasonal distribution of body sizes of the Wood Frog *(Lithobates sylvaticus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

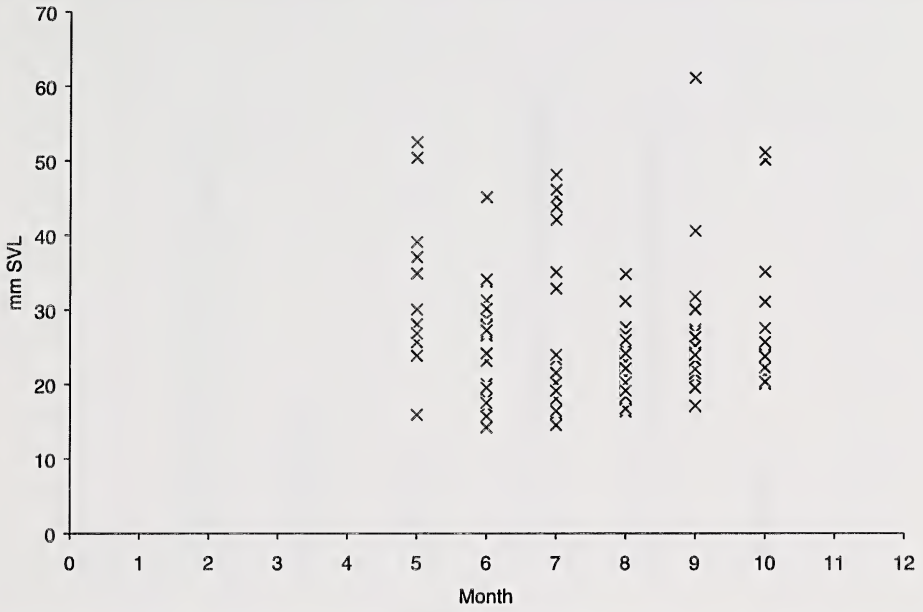


Figure 14. Seasonal activity of the Northern Dusky Salamander *(Desmognathus fuscus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

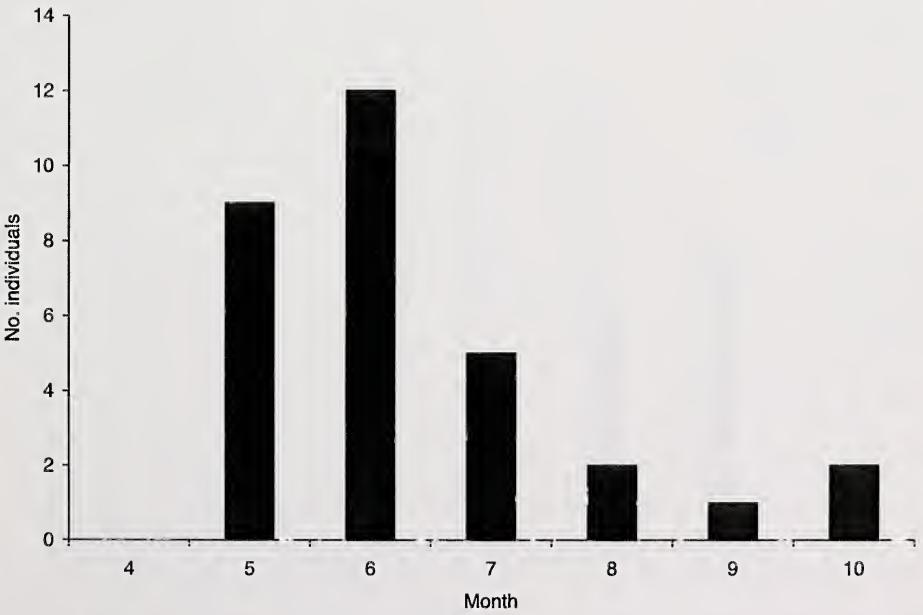


Figure 15. Seasonal distribution of body sizes of the Northern Dusky Salamander *(Desmognathus fuscus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

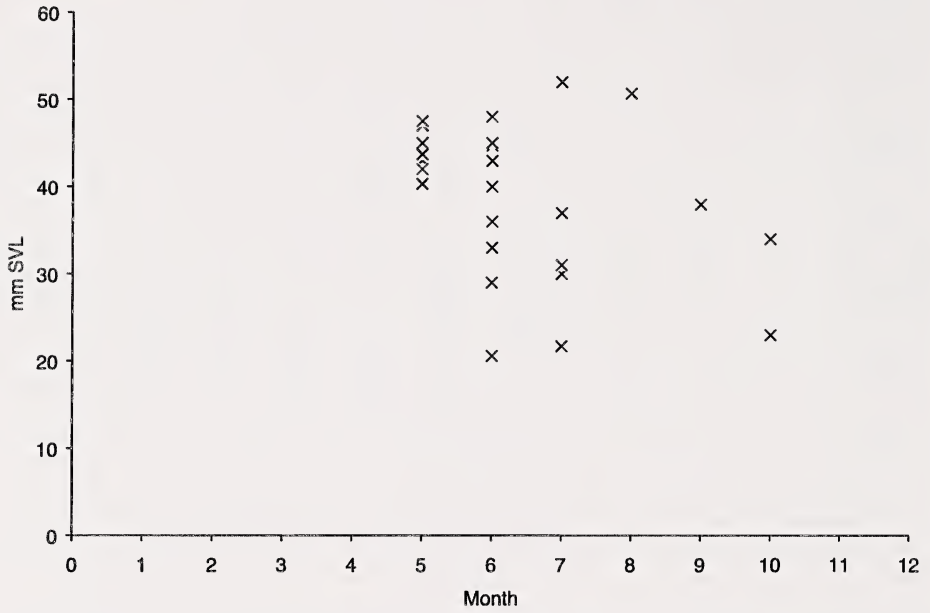


Figure 16. Seasonal activity of the Allegheny Dusky Salamander *(Desmognathus ochrophaeus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, in 1982.

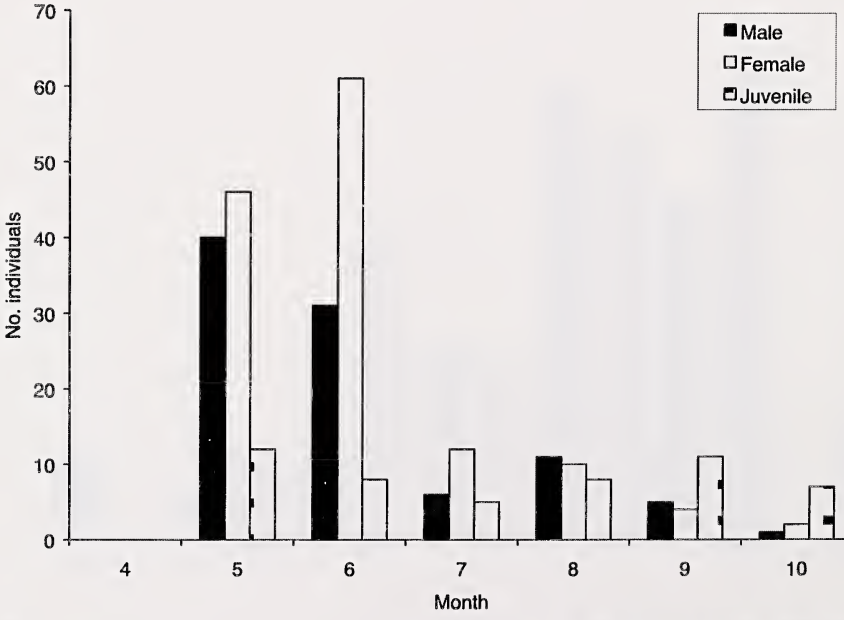


Figure 17. Seasonal activity of the Allegheny Dusky Salamander *(Desmognathus ochrophaeus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, in 1983.

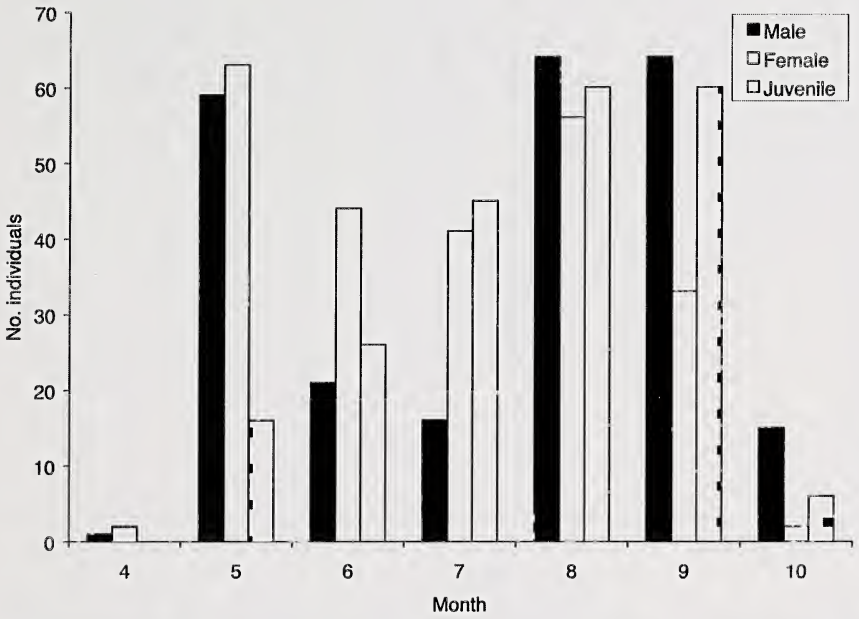


Figure 18. Seasonal distribution of body sizes of the Allegheny Dusky Salamander *(Desmognathus ochrophaeus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, in 1982.

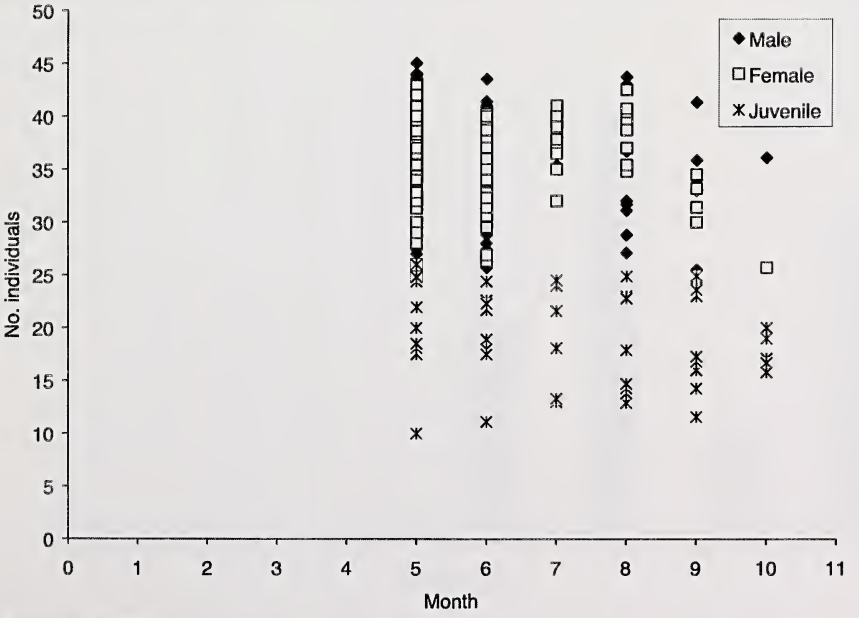


Figure 19. Seasonal distribution of body sizes of the Allegheny Dusky Salamander *(Desmognathus ochrophaeus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, in 1983.

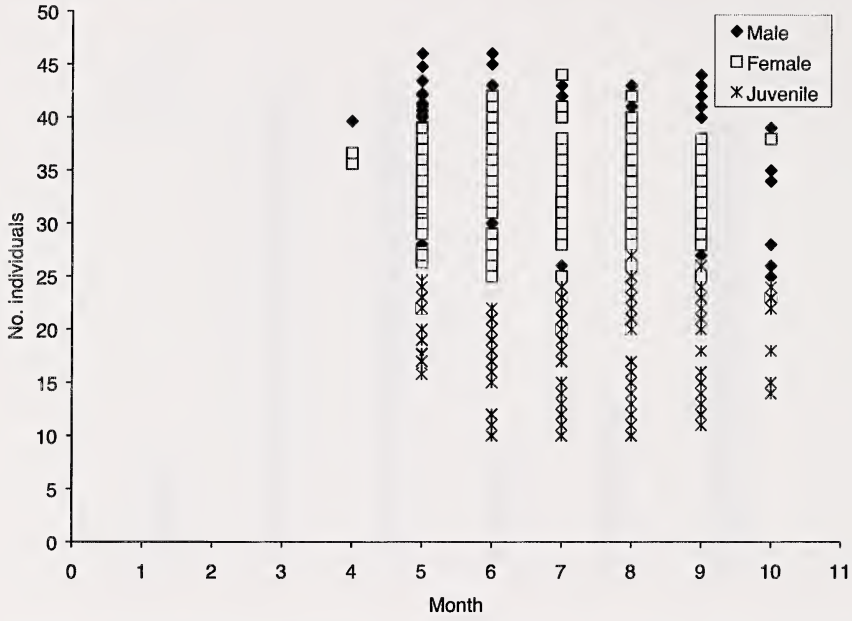


Figure 20. Ovarian cycle of the Allegheny Dusky Salamander *(Desmoganthus ochrophaeus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

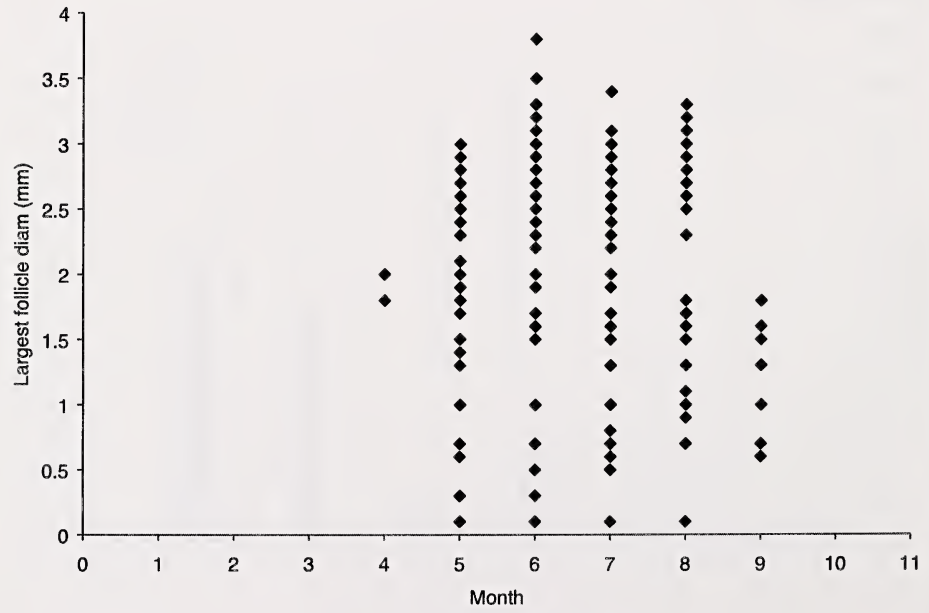


Figure 21. Relationship between clutch size and female body size of the Allegheny Dusky Salamander *(Desmoganthus ochrophaeus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

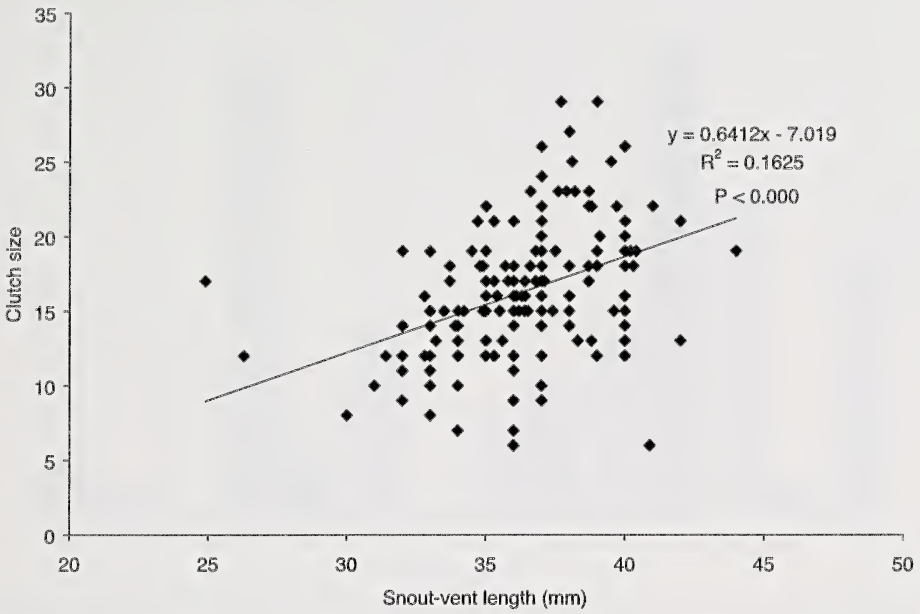


Figure 22. Seasonal activity of the Northern Two-lined Salamander *(Eurycea bislineata)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

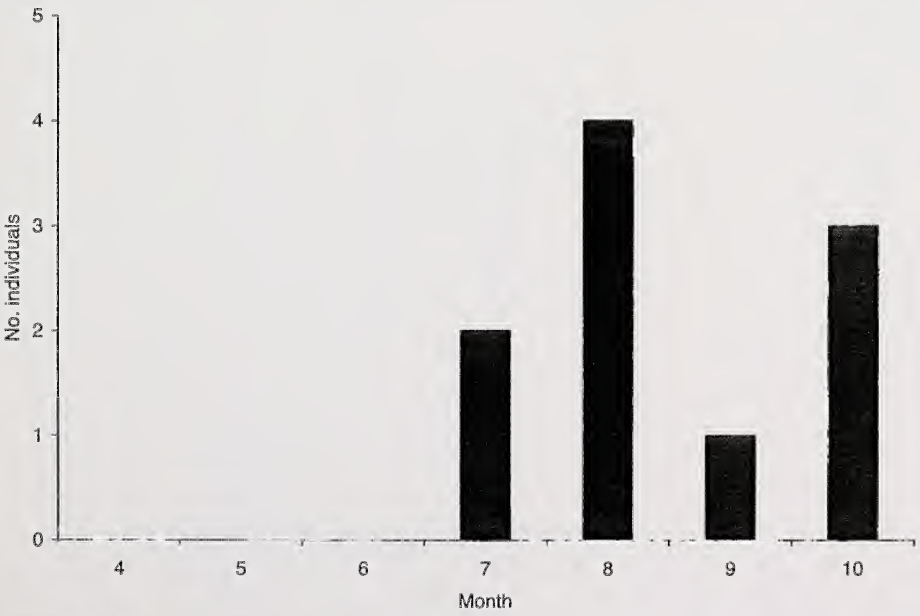


Figure 23. Seasonal activity of the Spring Salamander *(Gyrinophilis orphyriticus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

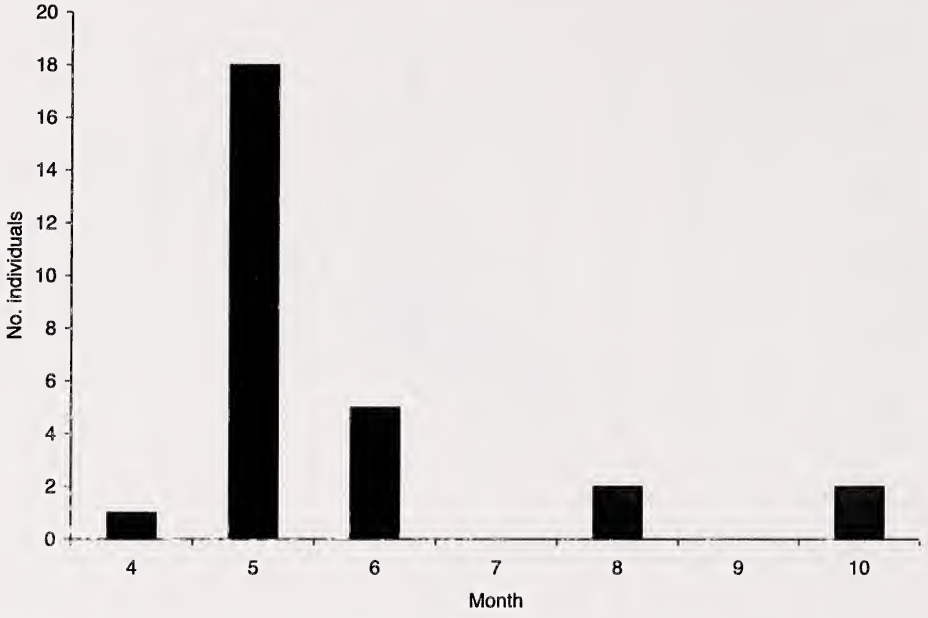


Figure 24. Seasonal distribution of body sizes of the Northern Spring Salamander *(Gyrinophilis porphyriticus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

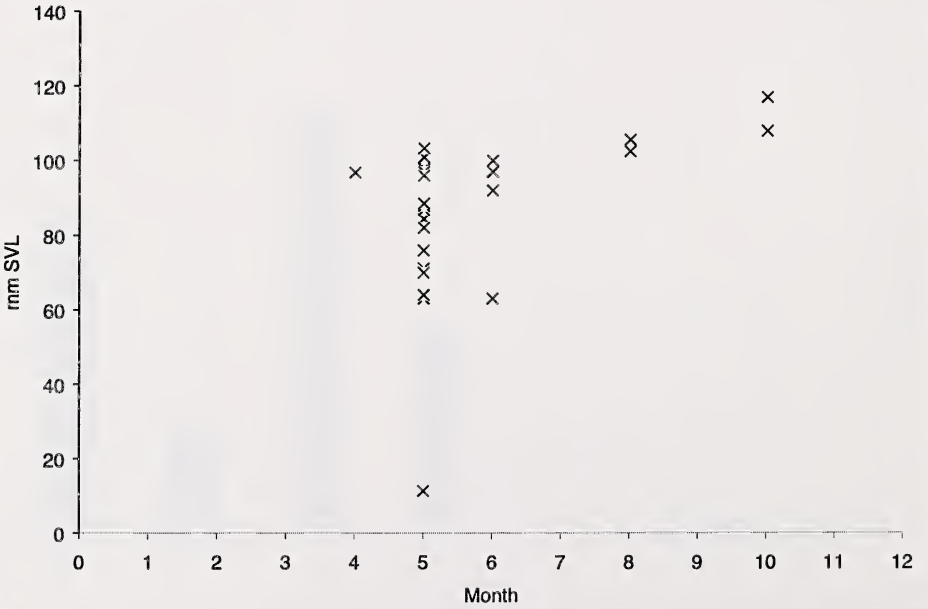


Figure 25. Seasonal activity of the Northern Redback Salamander *(Plethodon cinereus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

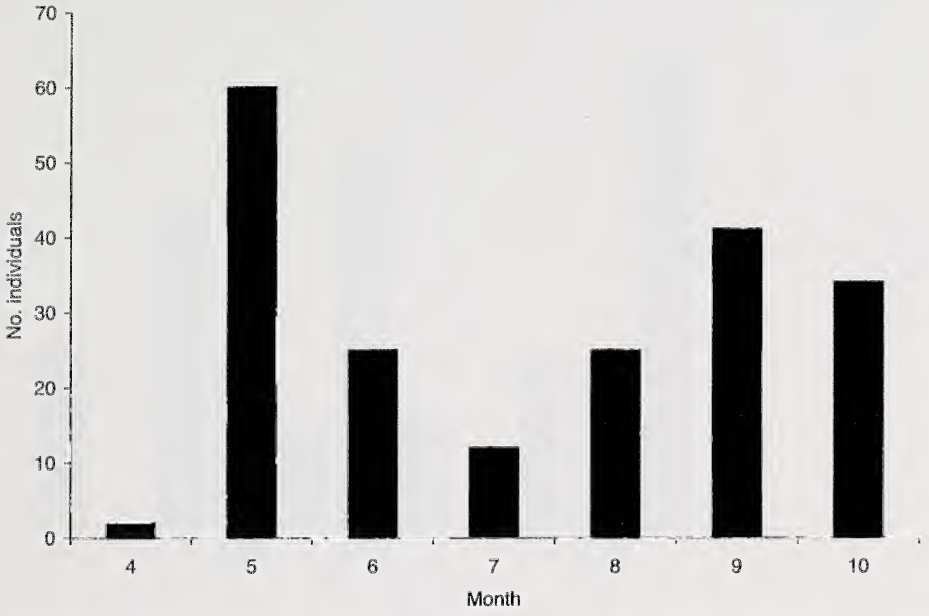


Figure 26. Seasonal distribution of body sizes of the Northern Redback Salamander *(Plethodon cinereus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

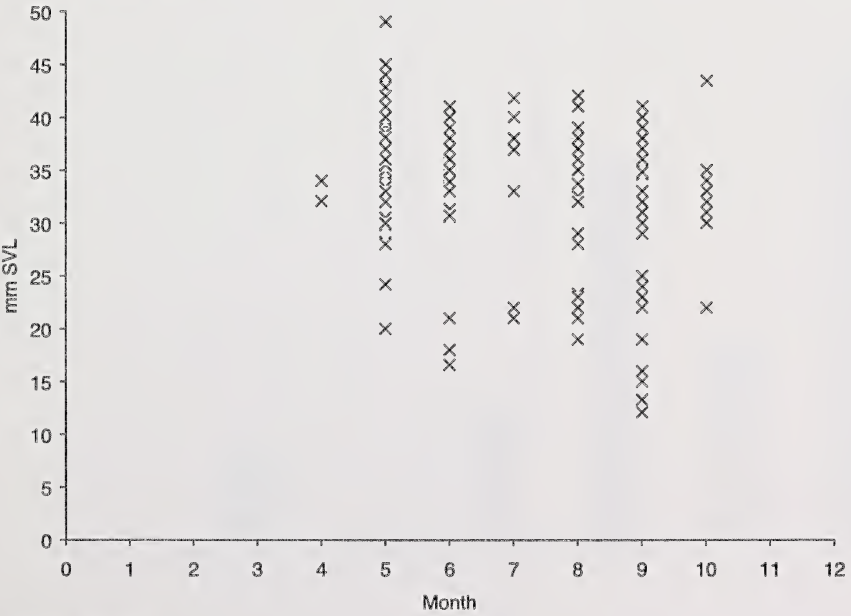


Figure 27. Seasonal activity of the Northern Slimy Salamander *(Plethodon glutinosus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

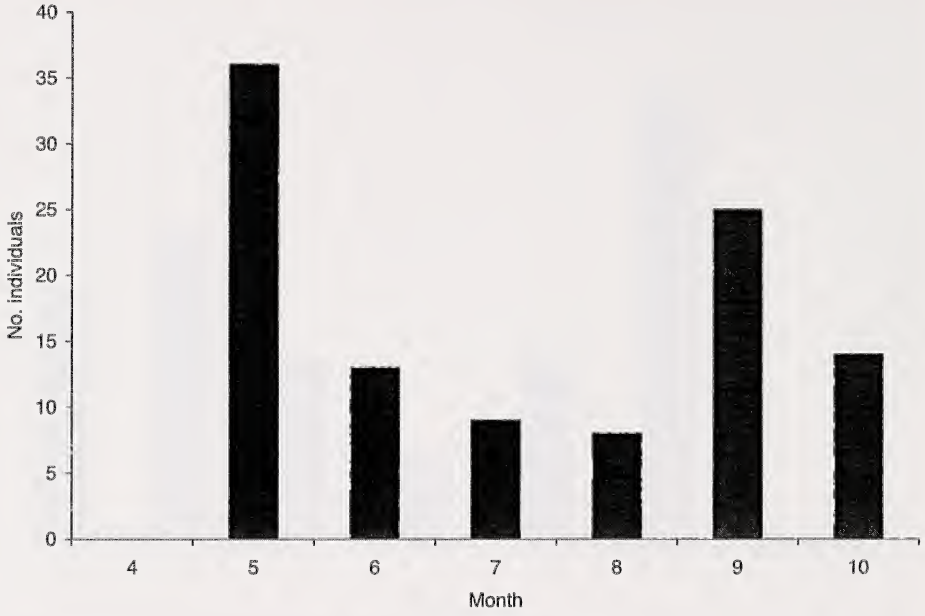


Figure 28. Seasonal distribution of body sizes of the Northern Slimy Salamander *(Plethodon glutinosus)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

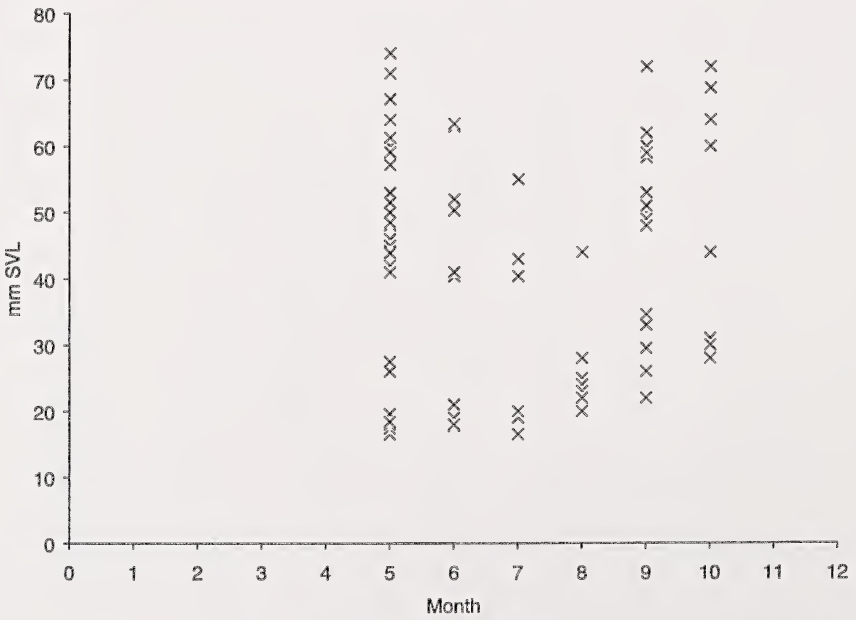


Figure 29. Seasonal activity of Wehrle's Salamander *(Plethodon wehrlei)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

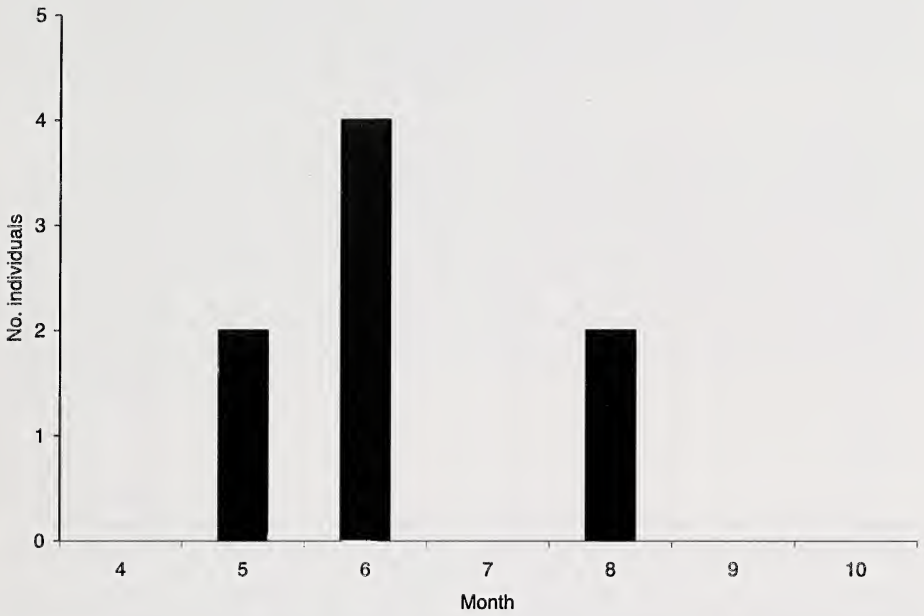


Figure 30. Seasonal activity of the Eastern Newt *(Notophthalmus viridescens)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.

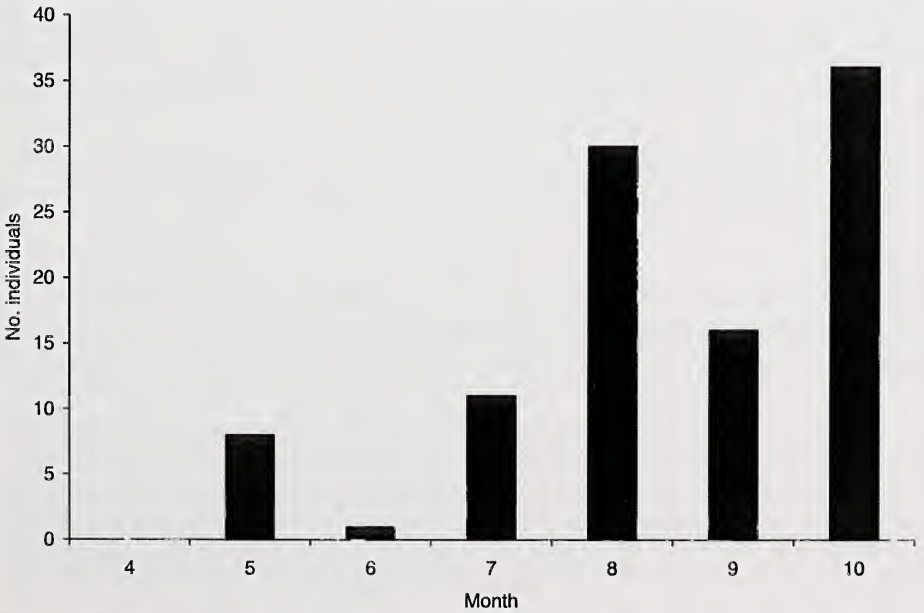
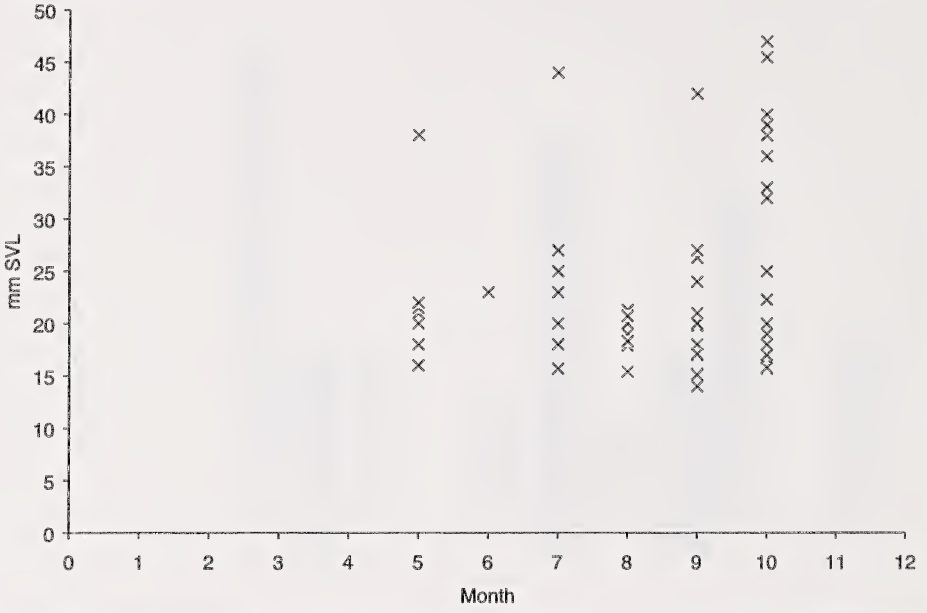


Figure 31. Seasonal distribution of body sizes of the Eastern Newt *(Notophthalmus viridescens)* at Powdermill Nature Reserve, Westmoreland County, Pennsylvania, during 1982-1983.



their third year of post-metamorphic life (Figures 4 and 5). Four gravid females were captured in May and a single gravid female was captured in August.

Hydidae

Pseudacris crucifer (Weid-Neuwied, 1838)- The Spring Peeper comprised 1.69% of all amphibian captures with 63 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the wet forested Leberman Cabin site and present at five of the sties (Table 1). Individuals were active during May to October and most active during August (Figure 6) at which time juveniles dominated the captures (Figure 7). Three gravid females were captured in May.

Ranidae

Lithobates catesbeianus (Shaw, 1802)- The Bullfrog comprised 0.03% of all amphibian captures with a single individual captured during the two years (Figure 2). The single individual was captured at the forested Along Strip Mine Road site (Table 1).

Lithobates clamitans (Latreille, 1801)- The Green Frog comprised 5.03% of all amphibian captures with 188 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the wet forested Leberman Cabin site, but were present at all sites (Table 1). Individuals were active during June to September and most active during July (Figure 8), all of which were dispersing juveniles (Figure 9).

Lithobates palustris (LeConte, 1825)- The Pickerel Frog comprised 2.30% of all amphibian captures with 86 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the wet forested Leberman Cabin site, but were present at all sites (Table 1). Individuals were active during May to October and most active during July (Figure 10) at which time most captures were of young individuals (Figure 11). By the middle of the following May, some of these young individuals exceeded 35 mm SVL (Figure 11).

Lithobates sylvaticus (LeConte, 1825)- The Wood Frog comprised 5.06% of all amphibian captures with 189 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Middle Strip Mine site, but were present at all sites (Table 1). Individuals were active during May to October and most active occurred in June and during August to September (Figure 12), at which time most captures were juveniles (Figure 13). The seasonal distribution of body sizes was suggestive of growth to c.a. 40 mm SVL by some individuals entering their second season of life (Figure 13).

Caudata

Plethodontidae

Desmognathus fuscus (Rafinesque, 1820)- The Northern Dusky Salamander comprised 0.83% of all amphibian captures with 31 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Along Strip Mine Road site and the species was present at five sites (Table 1). Individuals were active during May to October and most active occurred during May to June (Figure 14), at which time most individuals captured were adults (Figure 15). Enlarged ova were found in four females (2.3, 2.5, 2.6, 2.9 mm) in May and in one female (2.8 mm) in June.

Desmognathus monticola Dunn, 1916- The Seal Salamander comprised 0.05% of all amphibian captures with two individuals captured during the two years (Figure 2). Individuals were captured at the forested Byer and Calverly sites.

Desmognathus ochrophaeus Cope 1859- The Allegheny Dusky Salamander comprised 28.03% of all amphibian captures with 1,047 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Along Strip Mine Road site, but were at all sites (Table 1). Individuals were active during April to October with mixed size classes having been present throughout both years (Figures 16 and 17). Adults were detected most often during May to June in 1982 (Figure 16) and in August in 1983 (Figure 17). Data from 1983 revealed a steady increase in the number of juveniles, which leveled off during August to September (Figure 17). Hatchlings were present during May to September, and monthly distributions of body sizes (Figures 18 and 19) were suggestive of sexual maturity having been reached at approximately 14 months of age. Females (35.4 + 3.6 mm SVL; range = 24.9 - 44; N = 287) were gravid during May to August (Figure 20), female reproduction was biennial (Figure 20); mean clutch size was 16.3 eggs (range = 6 - 29; N = 164) and clutch size was positively related to female body size (Figure 21).

Eurcyea bislineata (Green, 1818)- The Northern Two-lined Salamander comprised 0.27% of all amphibian captures with 10 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Calverly site, but were present at five sites (Table 1). Individuals were active during July to October and most active in August and October (Figure 22).

Eurycea longicauda (Green, 1818)- The Longtail Salamander comprised 0.03% of all amphibian captures with a single individual captured during the two years (Figure 2). The single individual was captured at the forested Calverly site.

Gyrinophilis porphyriticus (Green, 1827)- The Spring Salamander comprised 0.75% of all amphibian captures with 28 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Along Strip Mine Road site, but were present at five sites (Table 1). Individuals were active during April to October and most active occurred during May (Figure 23). All but one individual collected was an adult (Figure 24).

Hemidactylium scutatum (Temminck and Schlegel, 1838)- The Four-toed Salamander comprised 0.05% of all amphibian captures with two individuals captured during the two years (Figure 2). Individuals were captured at the wet forested Leberman Cabin site and the forested Southeast Weaver Mill site (Table 1).

Plethodon cinereus (Green, 1818)- The Northern Redback Salamander comprised 5.36% of all amphibian captures with 200 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Along Strip Mine Road site, but were present at all sites (Table 1). Individuals were active during April to October, and were most active in May and September (Figure 25). The captures in May were dominated by adults, whereas those in September included many juveniles of various size classes (Figure 26). From the seasonal frequency of body size distribution (Figure 26), it appears that September juveniles were approximately 25 mm SVL by the following October and approximately 35 mm SVL the October after that. Thus, a P. cinereus having been born in fall 1982 could have bred in fall of 1984 or spring 1985.

The largest follicles in 11 females collected during May ranged 2.9 - 4.0 mm in diameter, and those in two females during June were 2.2 and 3.2 mm. Largest follicles in four females during September ranged from 1.0 to 1.1 mm, and a single female captured in October contained follicles no larger than 1.0 mm.

Plethodon glutinosus (Green, 1818)- The Northern Slimy Salamander comprised 2.81% of all amphibian captures with 105 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Along Strip Mine Road site, but were present at six sites (Table 1). Individuals were active during May to October and were most active in May and in September (Figure 27). Hatchlings

from summer to fall of 1981 would have appeared on the ground surface the following May as juveniles (~ 15 mm SVL; Figure 28). From the seasonal frequency of body size distribution (Figure 28), it appears that by the end of October 1982, juveniles would have reached approximately 30 mm SVL and would have been approximately 50 mm SVL by October 1983. Sexual maturity at approximately 56-65 mm SVL (Hulse et al., 2001) would have been reached by fall 1984, or about three years of age.

Plethodon wehrlei Fowler and Dunn, 1917- Wehrle's Salamander comprised 0.21% of all amphibian captures with eight individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the forested Along Strip Mine Road site, but were present at three sites (Table 1). Individuals were active during May to August and were most active during June (Figure 29).

Pseudotriton ruber (Latreille, 1801)- The Northern Red Salamander comprised 0.11% of all amphibian captures with four individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at Calverly and Middle Strip Mine sites, but he species was present at three sites (Table 1). One individual was captured in each of May (76 mm SVL), July, (45.4 mm SVL), September (79 mm SVL), and October (47 mm SVL).

Salamandridae

Notophthalmus viridescens (Rafinesque, 1820)- The Eastern Newt comprised 2.73% of all amphibian captures with 102 individuals captured during the two years (Figure 2). Per unit trap, most individuals were captured at the wet forest Leberman Cabin site, but were present at six sites (Table 1). Individuals were active during May to October and were most active in August and October (Figure 30). Mixed size classes were present (Figure 31). Individuals having just left the pond, wandering efts, and efts returning to the pond were captured during May to October (Figure 31). In the latter group, captures were most noticeable in October (Figure 31).

Discussion

Species list- The amphibian fauna detected in terrestrial trapping represented nearly the entire 21 amphibian species known from the station (Meshaka et al., 2008). One anuran and two salamander species were not captured in this study. The Mountain Chorus Frog, *Pseudacris brachyphona* (Cope, 1889), which most likely would have been detected during breeding season around the lentic aquatic habitat associated with the Leberman site, is thought to have been extirpated from the station (Meshaka et al., 2008). Among the salamanders, the absence of the sometimes terrestrially-active Spotted Salamander, *Ambystoma maculatum* (Shaw, 1802), appeared to be the result of the distance of the traps from the isolated seasonal pools that this species exclusively uses for breeding on the station. The second salamander species absent from this study was the Eastern Hellbender, *Cryptobranchus alleganiensis* (Daudin, 1803), a thoroughly aquatic species. The amphibian community of PNR is rich, with species that are associated with the Alleghenies and those with broader geographic distributions. Consequently,

PNR provides an optimal laboratory to test effects of land use changes and management strategies on a wide range of individual species as well as entire guilds, the applications of which extend both regionally and broadly over the Allegheny Mountain province.

Community structure- The community structure of the terrestrial aspect of the station's amphibian fauna in general mirrored that of the six forested sites, whereby two species, *A. americanus* and *D. ochrophaeus*, dominated the captures on land of an otherwise species-rich but uneven terrestrially-active amphibian community. To that end, terrestrial activity and association with mountain forests (Hulse et al., 2001) explained the high capture rates for the former species; however, its remarkable abundance underscored the high nutrient base and subsequent productivity of this Allegheny forest. As such, *A. americanus* would be appropriate to use as an indicator species in future forest amphibian monitoring projects at the station. *Desmognathus ochrophaeus*, the second most abundant amphibian, appeared to have been the ecological analog or replacement for *P. cinereus* in the predominantly wet forest of the station. In this connection, *D. ochrophaeus* comprised 68.0% of all salamander captures, whereas *P. cinereus*, the second most abundant salamander in this study and an often abundant forest inhabitant (Petranka, 1998), comprised only 13.0% of all salamander captures. In light of its high abundance across most sites, *D. ochrophaeus*, like *A. americanus*, represented a key species to monitor in the forest. Additionally, its association with cool clear streams would provide an added measure to evaluating water quality in the station's many forest streams. The lower terrestrial capture rates for most of the species was not especially surprising given their strong associations with habitats other than forest, such as streams in the case of *G. porphyriticus* (Hulse et al., 2001), *D. fuscus* (Krzysik, 1979), and D. monticola (Krzysik, 1979), or forest floors whose moisture levels were not as high as those of the lower elevation regions of the station (e.g., *P. cinereus, P. glutinosus,* and *P. wehrlei*). For example, among the plethodons, *P. wehrlei* was found to occur in drier habitat than *P. cinereus* (Pauley, 1978). Thus, relative abundance data must be interpreted within the context of the sampling method and its inherent biases.

Habitat association- Along Strip Mine Road there was a wide range of moisture conditions and this site had the most overall captures as well as the highest numbers of captures for eight individual species. The permanent and long-hydroperiod (but not permanent) grassy aquatic systems associated with the Leberman site explains the highest numbers of captures for *P. crucifer, L. clamitans, L. palustris,* and *N. viridescens* as well as one of the only two occurrences of *H. scutatum* at this site. This was also the site of the highest numbers of captures for five species and the second highest numbers of captures of *A. amercianus,* all of which contributed to the second place in overall captures of the Leberman site. The third highest numbers of *A. americanus* and second highest numbers of *D. ochrophaeus* explain the third place ranking in total captures of Southeast Weaver Mill site, a site in which no species were captured in their highest numbers. However, the Southeast Weaver Mill Site was notably the second of two sites in which *H. scutatum* was captured. Despite the highest numbers of *L. sylvaticus* at Middle Strip Mine site, the low number of species and low abundances of many of them explain its fourth place ranking in total numbers of amphibian captures. Calverly,

on the other hand, with the highest number of species detected for any site, ranked fifth place in overall captures. Despite few individuals captured, this site was notable for the highest numbers of *E. bislineata* and the only captures of *E. longicaucda,* two uncommonly captured species at PNR. Calverly also shared the most captures of *D. monticola* with Byer which, with the fewest *A. americanus* among forested sites, was the site with the lowest abundances of terrestrially active amphibians among these forested sites. It is important to note that, *D. monticola,* with a restricted geographic range in Pennsylvania, was found at only these latter two sites at PNR. Thus, the number of species and abundances vary distinctly among the forested sites.

Far and away, the least productive site for amphibians was the grassland habitat of Friedline. This site, so greatly inhabited by snakes (Meshaka et al., 2009), was inhabited by four of the six anurans and two of the 12 salamanders recorded in this study. All six of these amphibians were found in other habitats and their relative abundances were lowest or nearly so at this site. These findings suggested that the amphibian species found in this northeastern grassland do not share the strong affinities for this habitat as do those of the Great Plains (Collins, 1974).

Thus, with respect to habitat associations, grasslands provided the least value to the station's amphibian fauna. The forest sites, on the other hand, appeared to be an umbrella under which was detected a mosaic of structurally different sites with unique biological importance to the amphibian fauna of the station.

With respect to management, most of the species in this study are strongly associated with woodlands and they experience severe negative impacts, which can include extirpation, by deforestation (Petranka, 1998; Lannoo, 2005). Among these species, *G. porphoryticus* (Lannoo, 2005), *P. cinereus* (Petranka, 1998; Lannoo, 2005), *P. glutinosus* (Petranka, 1998), and *P. ruber* (Petranka, 1998) are known to be most abundant in mature forests, and *D. monticola* (Lannoo, 2005), *E. bislineata* (Petranka, 1998), *L. sylvaticus* (Lannoo, 2005), *P. cinereus* (Petranka, 1998; Lannoo, 2005), *P. glutinosus* (Petranka, 1998), and *P. ruber* (Petranka, 1998) are sensitive to intense tree harvesting practices. *Desmognathus monticola* presented a special case at PNR in light of its population having been near the edge of its geographic range (Conant and Collins, 1998).

Seasonal activity- The amphibian community was most active on the ground surface during May to September, and especially so during July to September. For the amphibians of PNR, August was the peak month of terrestrial activity for the majority of species. Among the anurans, seasonal terrestrial activity was unimodal, the peak of which occurred in July *(L. clamitans, L. palustris),* August *(A. americanus, P. crucifer),* or September *(L. sylvaticus).*

Among the salamanders, peak activity occurred in May *(G. porphyriticus, P. cinereus, P. glutinosus),* June *(D. fuscus, P. wehrlei),* August *(E. bislineata),* or October *(N. viridescens).* Among the salamanders for which sample sizes were at least 10 individuals, seasonal activity was unimodal in *D. fuscus* and *G. porphyriticus* and was bimodal in *E. bislineata, N. viridescens, P. cinereus,* and *P. glutinosus. Desmognathus ochrophaeus* presented a special case with respect to seasonal activity patterns. In 1982, activity was unimodal and peaked during May to June. The following year, with much larger sample sizes, seasonal activity was bimodal and peaked in May and even more

so in August. Juveniles was responsible for the latter peak.

Most of these species are closely associated with forests, and their peak surface activity months differed among them and, in one case, between years. Consequently, May to October with shifting peaks in amphibian terrestrial activity should be considered a sensitive time for conducting forest management plans such as logging of trees or herbicide treatment of exotic vegetation. It remains to be seen what further temporal limitations are warranted because of seasonal movements of *A. maculatum* to breeding pools and subsequent dispersal of metamorphosing young.

Growth- Incubation time and duration of the larval period are unknown for Pennsylvania populations of *D. ochrophaeus,* but the latter was thought to be short (Bishop, 1941; Hall, 1977). For example, whereas the larval period of *D. ochrophaeus* ranged from one to three weeks in duration (Marcum, 1994), that of Northeastern Ohio populations took place over a four to six month period (Orr, 1989). However, the seasonal distribution of body sizes of *D. ochrophaeus* at PNR was suggestive of sexual maturity having been reached approximately 14 months after larval transformation. In a northern Pennsylvania (Tioga County) population, males were thought to have matured in their third year of life (Hall, 1977). For Pennsylvania populations, both sexes were thought to reach sexual maturity in their second year after larval transformation (Hulse et al., 2001).

The seasonal distribution of body sizes among *P. cinereus* from PNR was similar to that of the species in Maryland, where sexual maturity was achieved at the beginning of the individual's third year of life (Sayler, 1966). Likewise, the seasonal distribution of body sizes and resulting growth trajectories of *P. glutinosus* at PNR placed this species at sexual maturity on or just after their third year of life. In Bedford County, of southern Pennsylvania, individuals were thought to reach sexual maturity at four years of age followed by first breeding a five years of age (Highton, 1962).

Reproduction- At PNR, female *D. ochrophaeus* laid their eggs annually at least during May to August, the clutch sizes (mean = 16.3 eggs) of which increased with increasing size of the female. In Tioga County, Pennsylvania, clutch size averaged 15.6 eggs, and a positive relationship between clutch size and female body size was also detected for this species (Hall, 1977). Mean clutch size was larger (mean = 19.0 eggs) in populations from northeastern Ohio (Pfingston, 1966). At PNR, females of *D. ochrophaeus* were gravid during May to August. In northern Pennsylvania, fresh eggs and newly hatched larvae were found in September and March (Bishop and Chrisp, 1933).

Most female *P. cinereus* captured in the spring contained yolked follicles that would be ready to be laid in June, which was suggestive of annual reproduction in Pennsylvania (Hulse et al., 2001). In Maryland, on the other hand, summer reproduction was biennial in this species (Sayler, 1966). In southwestern Pennsylvania (Bedford County), courtship of *P. glutinosus* occurred during fall and spring, and eggs were laid biennially during spring to early summer (Highton, 1962). With one exception in June, no gravid females were found after May at Highton's (1962) site, and clutch sizes averaged 16.7 eggs (range = 13-25).

Thus, the rate at which a species can recover after perturbations to the habitat would vary among sites depending upon the frequency of reproduction and clutch size. These differences should be taken into account when formulating management plans that at least initially might negatively impact terrestrially active components of the forest amphibian community.

Relationship to resource management- The ecological data in this study corroborate the importance of older forests to many amphibian species and provide a measure of amphibian community dynamics in older mixed deciduous forest. To that end, PNR is inhabited by many ecologically sensitive species. Some of them require cool, clear, lotic water in which to breed. Other species are most successful in mature forests. Poor management of these habitats would result in negative impacts to these species and be exacerbated in those species with delayed maturity and biennial reproduction. These data also provide the sorts of site-specific life history data needed to make sound decisions with respect to timing of potentially lethal management tools. Lastly, these data can serve as comparisons to, and benchmarks in, community-wide responses to habitat management plans not only for the resource management plans of PNR, but potentially for those in protected lands elsewhere in the Allegheny Mountains whose forest amphibian communities share these same species.

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